VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"JnanaSangama", Belgaum -590014, Karnataka.

LAB REPORT
on

Artificial Intelligence (23CS5PCAIN)

Submitted by

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in partial fulfillment for the award of the degree of
BACHELOR OF ENGINEERING
in
COMPUTER SCIENCE AND ENGINEERING

B.M.S. COLLEGE OF ENGINEERING
(Autonomous Institution under VTU)
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B.M.S. College of Engineering,

Bull Temple Road, Bangalore 560019

(Affiliated To Visvesvaraya Technological University, Belgaum)

Department of Computer Science and Engineering

CERTIFICATE

This is to certify that the Lab work entitled **"Artificial Intelligence (23CS5PCAIN)"** carried out by **TARUN M M (1BM22CS306),** who is a bonafide student of **B.M.S. College of Engineering.** It is in partial fulfillment for the award of **Bachelor of Engineering in Computer Science and Engineering** of the Visvesvaraya Technological University, Belgaum. The Lab report has been approved as it satisfies the academic requirements in respect of an Artificial Intelligence(23CS5PCAIN) work prescribed for the said degree.

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Github Link: https://github.com/tmagaji7/AI_LAB

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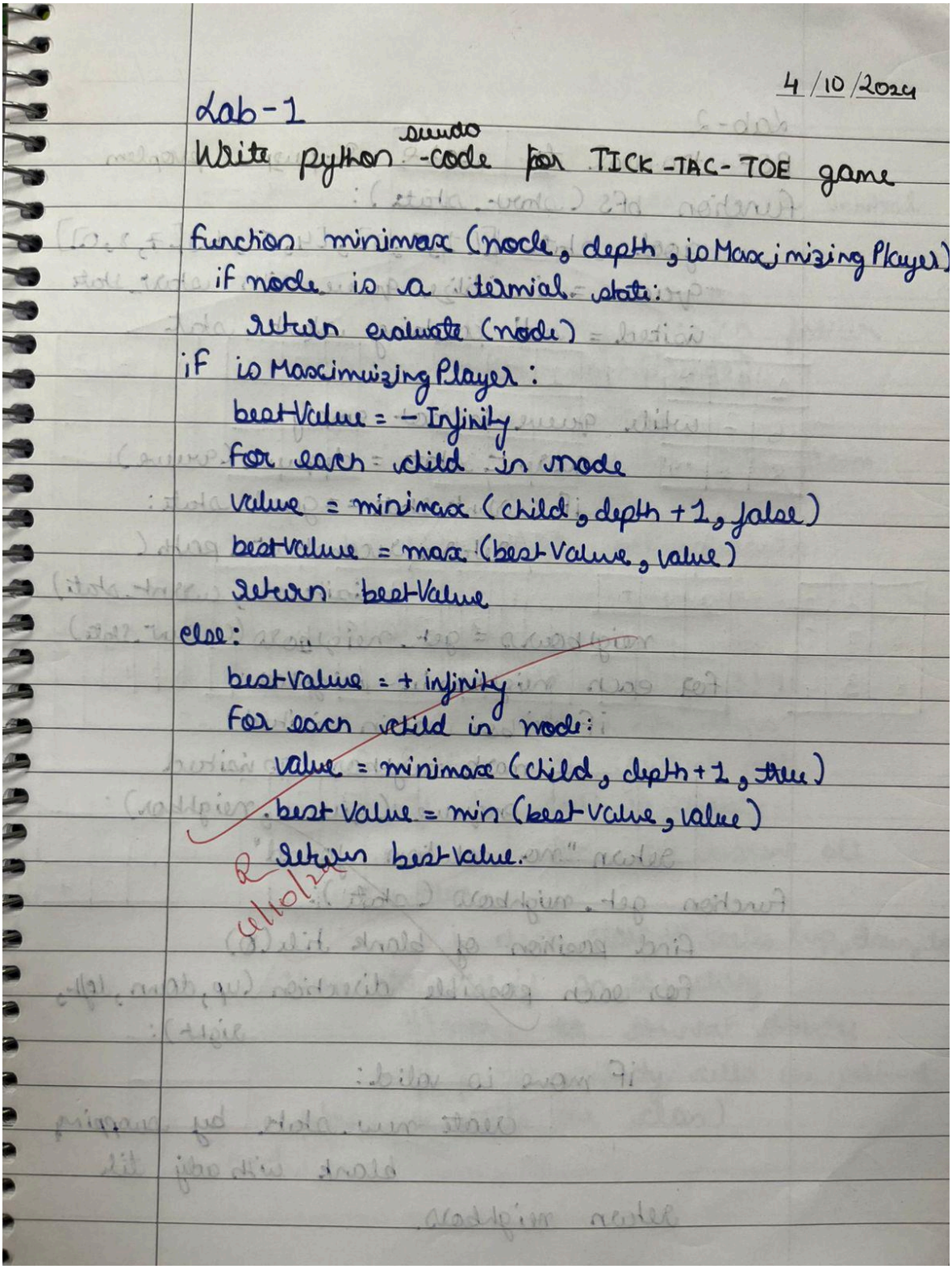


4/10/2024

Lab-1

Write python pseudo-code for TICK-TAC-TOE game

```
function minimax (node, depth, isMaximizingPlayer)
  if node is a termial state:
    return evaluate (node)
if isMaximizingPlayer:
    bestValue = -Infinity
    for each child in node
    value = minimax (child, depth + 1, false)
    bestvalue = max (bestValue, value)
    return bestValue
else:
    bestvalue = + infinity
    For each child in node:
      value = minimax (child, depth + 1, true)
      best Value = min (bestvalue, value)
      return bestvalue.
```

Code

```
board = {1: ' ', 2: ' ', 3: ' ',
        4: ' ', 5: ' ', 6: ' ',
        7: ' ', 8: ' ', 9: ' '}


def printBoard(board):
    print(board[1] + '|' + board[2] + '|' + board[3])
    print('-+-+-')
    print(board[4] + '|' + board[5] + '|' + board[6])2
    print('-+-+-')
    print(board[7] + '|' + board[8] + '|' + board[9])
    print('\n')


def spaceFree(pos):
    return board[pos] == ' '


def checkWin():
    win_conditions = [
        (1, 2, 3), (4, 5, 6), (7, 8, 9),  # Rows
        (1, 4, 7), (2, 5, 8), (3, 6, 9),  # Columns
        (1, 5, 9), (3, 5, 7)  # Diagonals
    ]
    for a, b, c in win_conditions:
```

```
        if board[a] == board[b] == board[c] and board[a] != ' ':
            return True
    return False


def checkMoveForWin(move):
    win_conditions = [
        (1, 2, 3), (4, 5, 6), (7, 8, 9),
        (1, 4, 7), (2, 5, 8), (3, 6, 9),
        (1, 5, 9), (3, 5, 7)
    ]
    for a, b, c in win_conditions:
        if board[a] == board[b] == move and board[a] != ' ':
            return True
    return False


def checkDraw():
    return all(board[key] != ' ' for key in board.keys())


def insertLetter(letter, position):
    if spaceFree(position):
        board[position] = letter
        printBoard(board)
        if checkDraw():
            print('Draw!')
        elif checkWin():
            if letter == 'X':
                print('Bot wins!')
            else:
```

```
            print('You win!')
            return
        else:
            print('Position taken, please pick a different position.')
            position = int(input('Enter new position: '))
            insertLetter(letter, position)

player = 'O'
bot = 'X'

def playerMove():
    position = int(input('Enter position for O: '))
    insertLetter(player, position)

def compMove():
    bestScore = -1000
    bestMove = 0
    for key in board.keys():
        if board[key] == ' ':
            board[key] = bot
            score = minimax(board, False)
            board[key] = ' '
            if score > bestScore:
                bestScore = score
                bestMove = key
    insertLetter(bot, bestMove)

def minimax(board, isMaximizing):
```

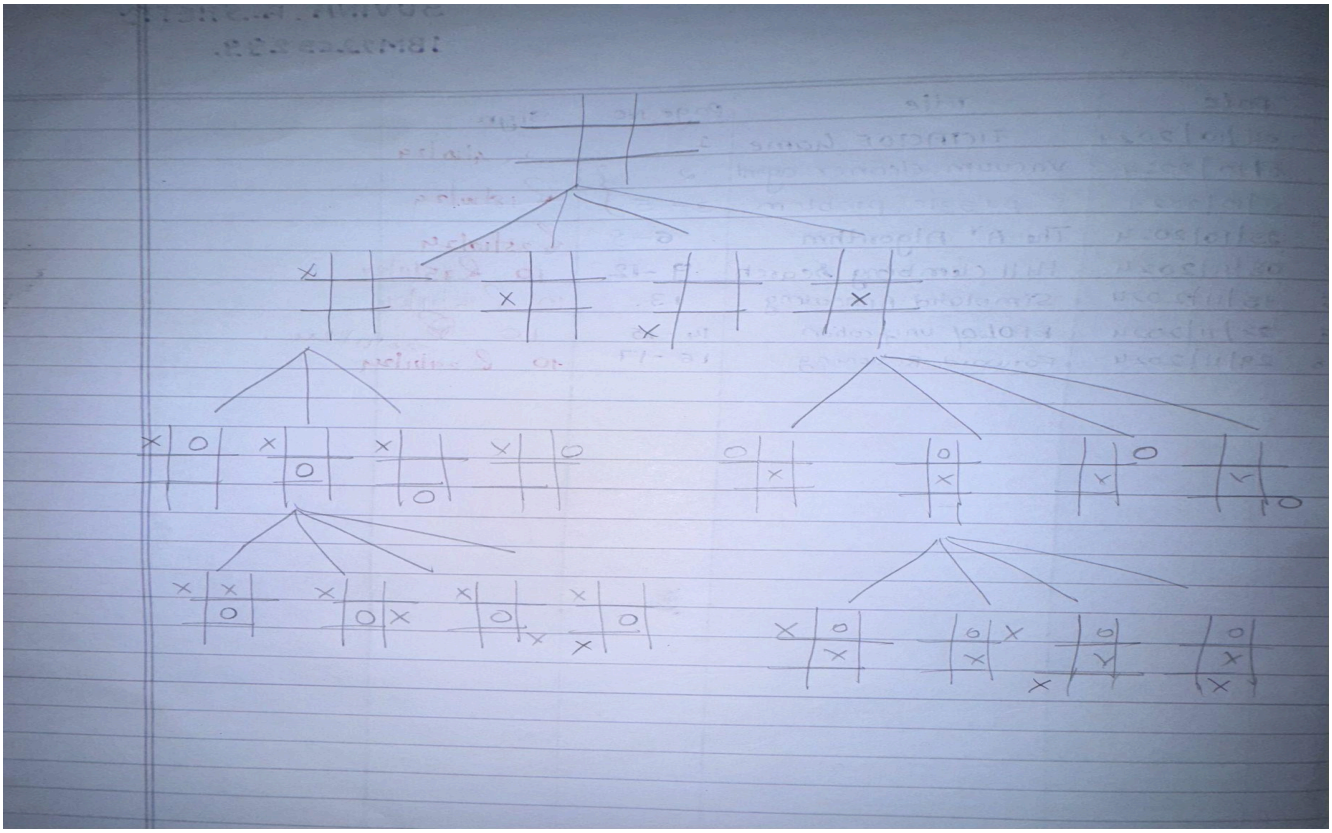
```
    if checkMoveForWin(bot):
        return 1
    elif checkMoveForWin(player):
        return -1
    elif checkDraw():
        return 0

    if isMaximizing:
        bestScore = -1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = bot
                score = minimax(board, False)
                board[key] = ' '
                bestScore = max(score, bestScore)
        return bestScore
    else:
        bestScore = 1000
        for key in board.keys():
            if board[key] == ' ':
                board[key] = player
                score = minimax(board, True)
                board[key] = ' '
                bestScore = min(score, bestScore)
        return bestScore

print("TARUN M M")
print("USN:1BM22CS306\n")
```

```
while not checkWin() and not checkDraw():
    compMove()
    if checkWin() or checkDraw():
        break
    playerMove()
```

Output Snapshot

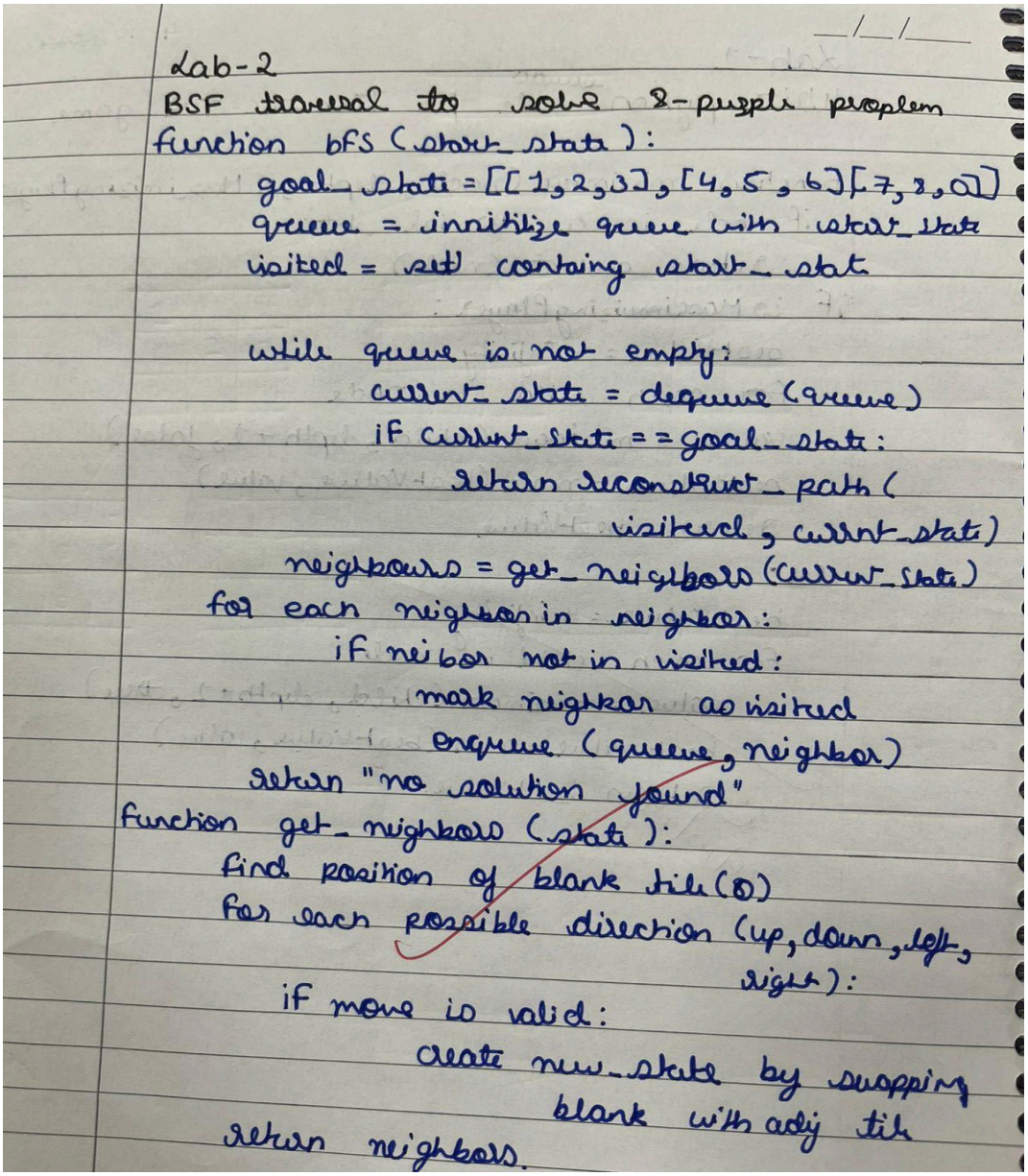
```
 X| |
 -+-+-
  | |
 -+-+-
  | |


 Enter position for O: 2
 X|O|
 -+-+-
  | |
 -+-+-
  | |


 X|O|
 -+-+-
 X| |
 -+-+-
  | |


 Enter position for O: 7
 X|O|
 -+-+-
 X| |
 -+-+-
 O| |
```

State Space Tree



Program 2 - 8 Puzzle Using BFS

Algorithm



```
Lab-2
BSF traversal to solve 8-puzzle problem
function bfs (start_state):
    goal_state = [[1,2,3],[4,5,6],[7,8,0]]
    queue = initilize queue with start_state
    visited = set() containg start_state

    while queue is not empty:
        current_state = dequeue (queue)
        if current_state == goal_state:
            return reconstruct_path (
                visited, current_state)
        neighbours = get_neighbors (current_state)
    for each neighbor in neighbor:
        if neibor not in visited:
            mark neighbor as visited
            enqueue (queue, neighbor)
    return "no solution found"
function get_neighbors (state):
    find position of blank tile (0)
    for each possible direction (up, down, left,
                                 right):
        if move is valid:
            create new_state by swapping
                blank with adj tile
    return neighbors.
```

Code

```
#BFS
from collections import deque

class PuzzleState:
    def __init__(self, board, zero_position, path=[]):
        self.board = board
        self.zero_position = zero_position
        self.path = path

    def is_goal(self):
        return self.board == [1, 2, 3, 4, 5, 6, 7, 8, 0]

    def get_possible_moves(self):
        moves = []
        row, col = self.zero_position
        directions = [(0, 1), (1, 0), (0, -1), (-1, 0)]  # Right, Down, Left, Up

        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                new_board = self.board[:]
                # Swap zero with the adjacent tile
                new_board[row * 3 + col], new_board[new_row * 3 + new_col] = new_board[new_row
* 3 + new_col], new_board[row * 3 + col]
                moves.append(PuzzleState(new_board, (new_row, new_col), self.path + [new_board]))
        return moves

def bfs(initial_state):
    queue = deque([initial_state])
    visited = set()

    while queue:
        current_state = queue.popleft()
        # Show the current board
        print("Current Board State:")
```

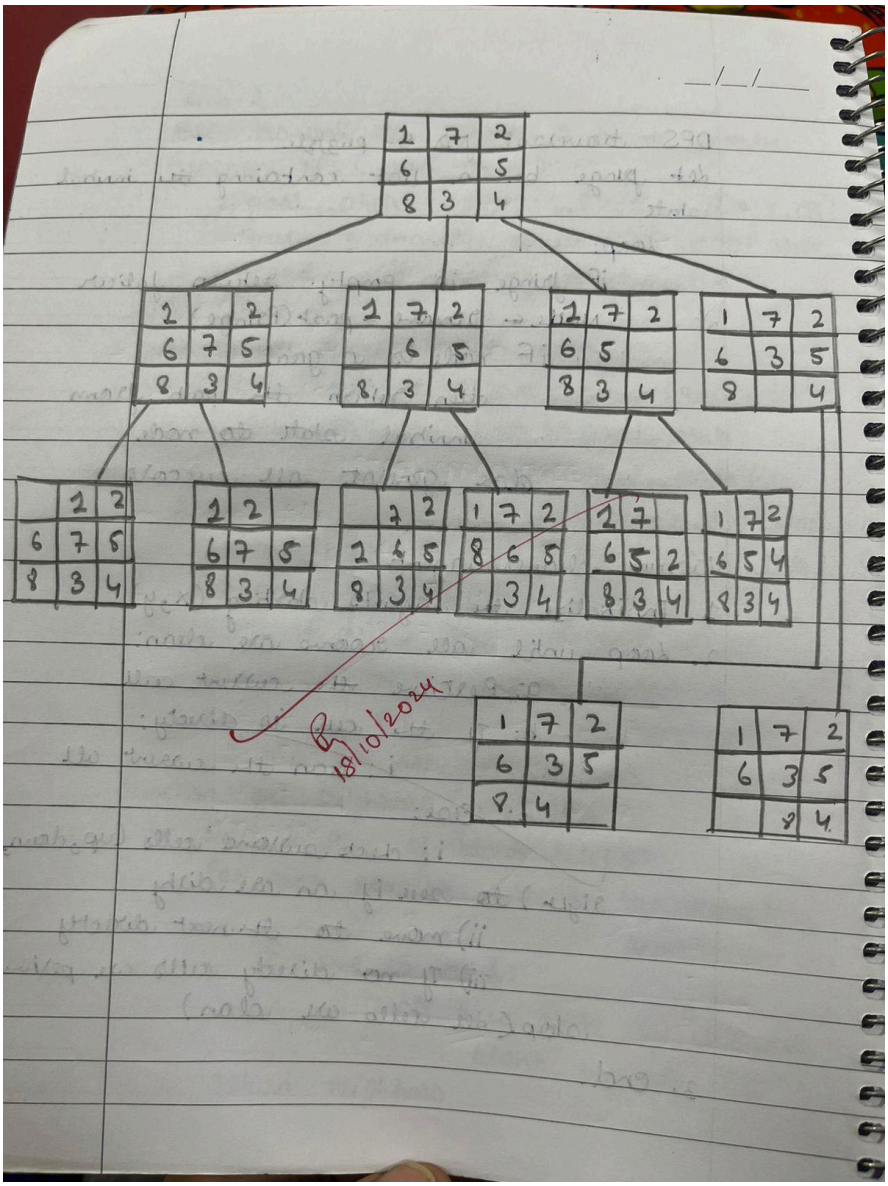
```
        print_board(current_state.board)
        print()

        if current_state.is_goal():
            return current_state.path
        visited.add(tuple(current_state.board))

        for next_state in current_state.get_possible_moves():
            if tuple(next_state.board) not in visited:
                queue.append(next_state)

    return None

def print_board(board):
    for i in range(3):
        print(board[i * 3:i * 3 + 3])

def main():
    print("Enter the initial state of the 8-puzzle (use 0 for the blank tile, e.g., '1 2 3 4 5 6 7 8 0'): ")
    user_input = input()
    initial_board = list(map(int, user_input.split()))

    if len(initial_board) != 9 or set(initial_board) != set(range(9)):
        print("Invalid input! Please enter 9 numbers from 0 to 8.")
        return

    zero_position = initial_board.index(0)
    initial_state = PuzzleState(initial_board, (zero_position // 3, zero_position % 3))
    solution_path = bfs(initial_state)

    if solution_path is None:
        print("No solution found.")
    else:
        print("Solution found in", len(solution_path), "steps.")
        for step in solution_path:
            print_board(step)
            print()

if __name__ == "__main__":
    main()
```

```
print("-------------")
print("TARUN M M")
print("1BM22CS306")
```

Output Snapshot

```
Current Board State:
[1, 2, 0]
[4, 6, 3]
[7, 5, 8]

Current Board State:
[1, 2, 3]
[4, 5, 6]
[7, 8, 0]

Solution found in 2 steps.
[1, 2, 3]
[4, 5, 6]
[7, 0, 8]

[1, 2, 3]
[4, 5, 6]
[7, 8, 0]

-------------
```

State Space Tree



8 puzzle using DFS

Code

```
from collections import deque

print("TARUN M M")
print("1BM22CS306")
print("--------")

def get_user_input(prompt):
    board = []
    print(prompt)
    for i in range(3):
        row = list(map(int, input(f"Enter row {i + 1} (space-separated numbers, use 0 for empty space):
").split()))
        board.append(row)
    return board

def is_solvable(board):
    flattened_board = [tile for row in board for tile in row if tile != 0]
    inversions = 0
    for i in range(len(flattened_board)):
        for j in range(i + 1, len(flattened_board)):
            if flattened_board[i] > flattened_board[j]:
                inversions += 1
    return inversions % 2 == 0

class PuzzleState:
    def __init__(self, board, moves=0, previous=None):
        self.board = board
        self.empty_tile = self.find_empty_tile()
        self.moves = moves
        self.previous = previous
```

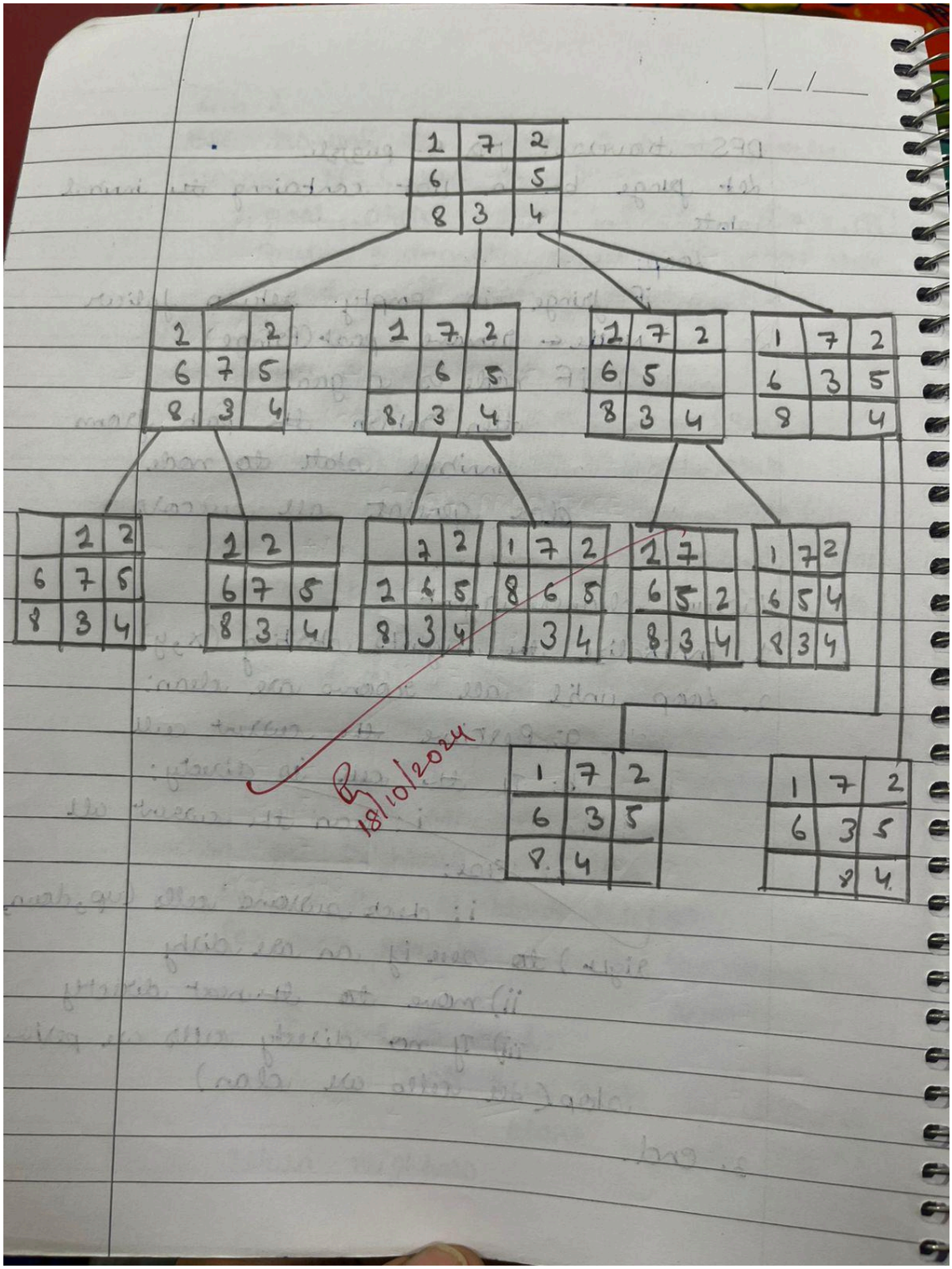
```
    def find_empty_tile(self):
        for i in range(3):
            for j in range(3):
                if self.board[i][j] == 0:
                    return (i, j)

    def is_goal(self, goal_state):
        return self.board == goal_state

    def get_possible_moves(self):
        row, col = self.empty_tile
        possible_moves = []
        directions = [(1, 0), (-1, 0), (0, 1), (0, -1)]  # down, up, right, left
        for dr, dc in directions:
            new_row, new_col = row + dr, col + dc
            if 0 <= new_row < 3 and 0 <= new_col < 3:
                # Make the move
                new_board = [row[:] for row in self.board]  # Deep copy
                new_board[row][col], new_board[new_row][new_col] = new_board[new_row][new_col],
new_board[row][col]
                possible_moves.append(PuzzleState(new_board, self.moves + 1, self))
        return possible_moves

def dfs(initial_state, goal_state):
    stack = [initial_state]
    visited = set()
    while stack:
        current_state = stack.pop()
        # If we find the goal, return the state
        if current_state.is_goal(goal_state):
            return current_state
        # Convert board to a tuple for the visited set
        state_tuple = tuple(tuple(row) for row in current_state.board)
        # If we've already visited this state, skip it
        if state_tuple not in visited:
            visited.add(state_tuple)
```

```
            for next_state in current_state.get_possible_moves():
                stack.append(next_state)
    return None  # No solution found

def print_solution(solution):
    path = []
    while solution:
        path.append(solution.board)
        solution = solution.previous
    for state in reversed(path):
        for row in state:
            print(row)
        print()

if __name__ == "__main__":
    # Get user input for initial and goal states
    initial_board = get_user_input("Enter the initial state of the puzzle:")
    goal_board = get_user_input("Enter the goal state of the puzzle:")

    if is_solvable(initial_board):
        initial_state = PuzzleState(initial_board)
        solution = dfs(initial_state, goal_board)
        if solution:
            print("Solution found in", solution.moves, "moves:")
            print_solution(solution)
        else:
            print("No solution found.")
    else:
        print("This puzzle is unsolvable.")
```

Output Snapshot

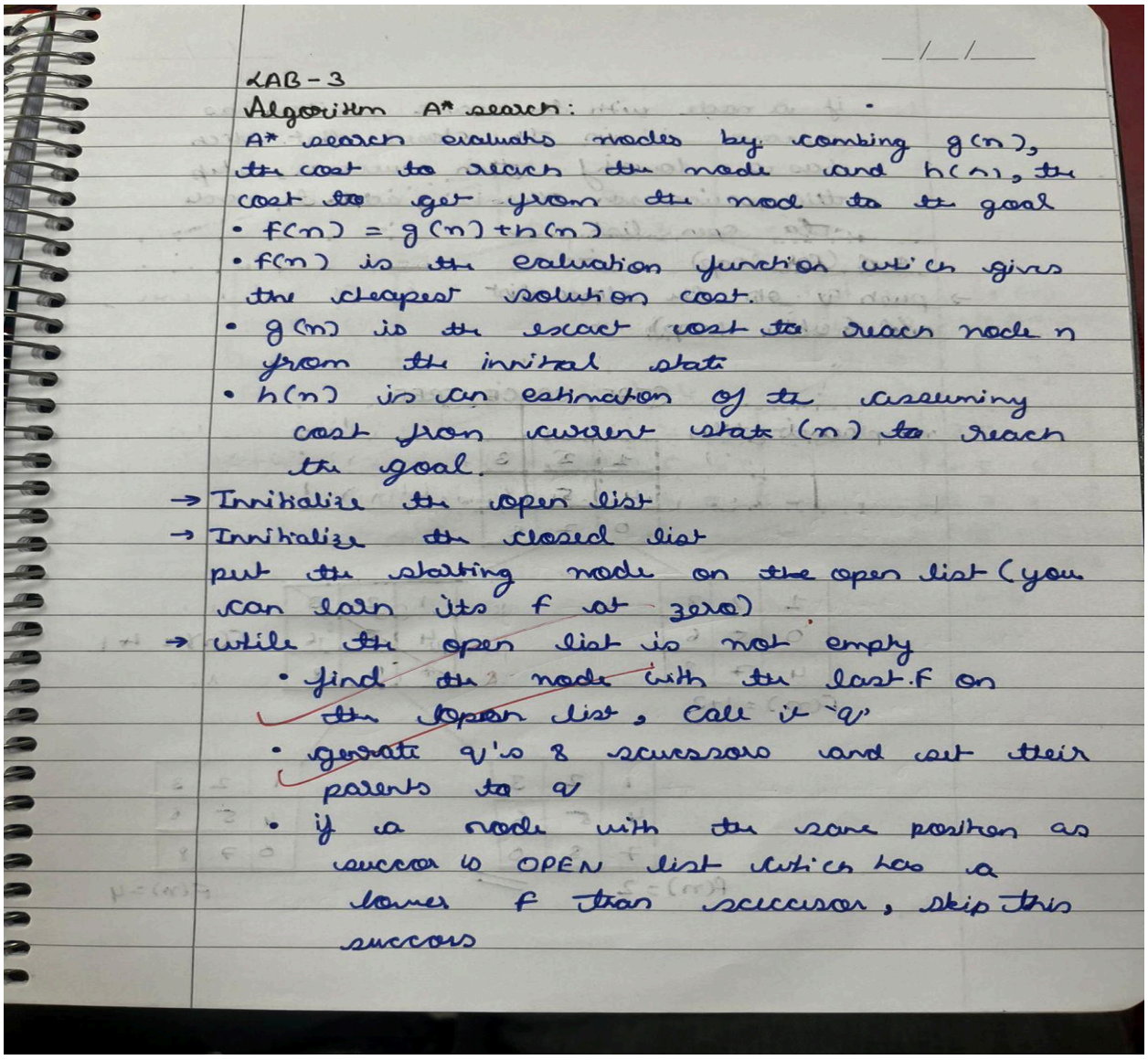
```
--------
Enter the initial state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 0 5
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 6
Enter the goal state of the puzzle:
Enter row 1 (space-separated numbers, use 0 for empty space): 1 2 3
Enter row 2 (space-separated numbers, use 0 for empty space): 4 5 6
Enter row 3 (space-separated numbers, use 0 for empty space): 7 8 0
Solution found in 30 moves:
[1, 2, 3]
[4, 0, 5]
[7, 8, 6]

[1, 2, 3]
[0, 4, 5]
[7, 8, 6]

[0, 2, 3]
[1, 4, 5]
[7, 8, 6]
```

StateSpaceTree



Program 03 - 8 Puzzle Using A*

Algorithm



LAB - 3

Algorithm A* search:

A* search evaluates nodes by combing g(n), the cost to reach the node and h(n), the cost to get from the node to the goal

- f(n) = g(n) + h(n)
- f(n) is the evaluation function which gives the cheapest solution cost.
- g(n) is the exact cost to reach node n from the initial state
- h(n) is an estimation of the assuming cost from current state (n) to reach the goal.

→ Initialize the open list

→ Initialize the closed list

put the starting node on the open list (you can leave its f at zero)

→ while the open list is not empty

- find the node with the last f on the open list, call it "q"
- generate q's 8 successors and set their parents to q
- if a node with the same position as successor is OPEN list which has a lower f than successor, skip this successor

Code

MANHATTAN DISTANCE

```
#Manhattan Distance
import heapq

class Node:
    def __init__(self, position, parent=None):
        self.position = position
        self.parent = parent
        self.g = 0  # Cost from start to this node
        self.h = 0  # Heuristic cost from this node to target
        self.f = 0  # Total cost

    def __lt__(self, other):
        return self.f < other.f

def heuristic(a, b):
    # Manhattan distance
    return abs(a[0] - b[0]) + abs(a[1] - b[1])

def astar(start, goal, grid):
    open_list = []
    closed_list = set()
    start_node = Node(start)
    goal_node = Node(goal)
    heapq.heappush(open_list, start_node)

    while open_list:
```

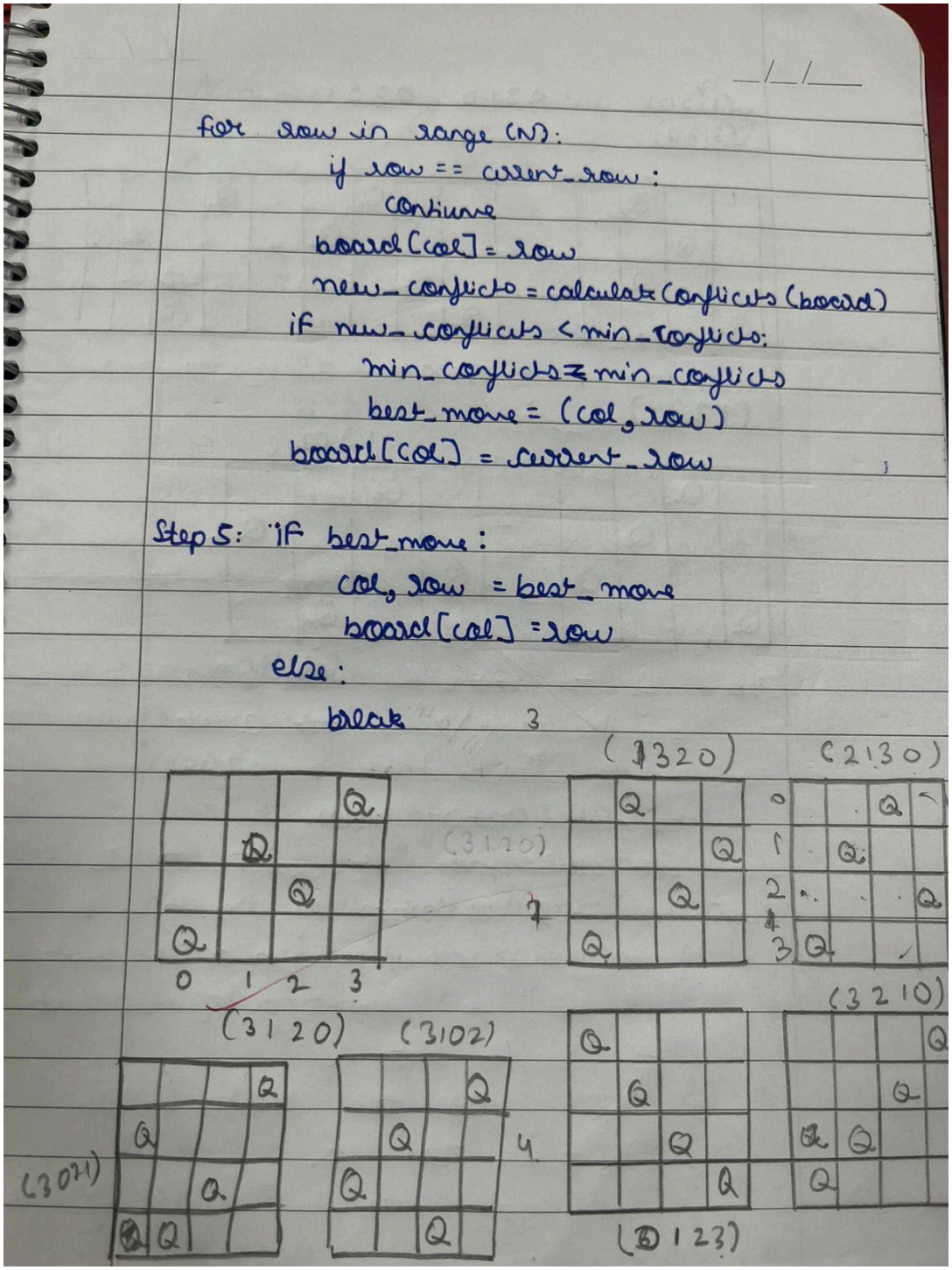
```
        current_node = heapq.heappop(open_list)
        closed_list.add(current_node.position)

        # Goal check
        if current_node.position == goal:
            path = []
            while current_node:
                path.append(current_node.position)
                current_node = current_node.parent
            return path[::-1]  # Return reversed path

        # Generate neighbors
        neighbors = [
            (current_node.position[0] + dx, current_node.position[1] + dy)
            for dx, dy in [(-1, 0), (1, 0), (0, -1), (0, 1)]
        ]

        for next_position in neighbors:
            # Check if within bounds and not a wall (assuming 0 is free space)
            if (0 <= next_position[0] < len(grid) and
                0 <= next_position[1] < len(grid[0]) and
                grid[next_position[0]][next_position[1]] == 0):

                if next_position in closed_list:
                    continue

                neighbor_node = Node(next_position, current_node)
                neighbor_node.g = current_node.g + 1
                neighbor_node.h = heuristic(next_position, goal)
                neighbor_node.f = neighbor_node.g + neighbor_node.h

                # Check if this neighbor is already in the open list
                if any(neighbor.position == neighbor_node.position and neighbor.f <= neighbor_node.f for
neighbor in open_list):
                    continue
```

```
            heapq.heappush(open_list, neighbor_node)

    return []  # Return empty path if no path found

# Example usage
if __name__ == "__main__":
    grid = [
        [0, 0, 0, 0, 0],
        [0, 1, 1, 1, 0],
        [0, 0, 0, 0, 0],
        [0, 1, 1, 0, 0],
        [0, 0, 0, 0, 0]
    ]
    start = (0, 0)
    goal = (4, 4)
    path = astar(start, goal, grid)
    print("Path from start to goal:", path)
    print("TARUN M M")
    print("1BM22CS306")
```

Output Snapshot

```
Path from start to goal: [(0, 0), (1, 0), (2, 0), (2, 1), (2, 2), (2, 3), (3, 3), (4, 3), (4, 4)]
```

State Space Tree



MISPLACED TILES

#Misplaced Tiles

```
import heapq


class PuzzleState:
    def __init__(self, board, g=0):
        self.board = board
        self.g = g  # Cost from start to this state
        self.zero_pos = board.index(0)  # Position of the empty space


    def h(self):
        # Calculate the number of misplaced tiles (Misplaced Tile Heuristic)
        return sum(1 for i in range(9) if self.board[i] != 0 and self.board[i] != i + 1)


    def f(self):
        return self.g + self.h()


    def get_neighbors(self):
        neighbors = []
        x, y = divmod(self.zero_pos, 3)
        directions = [(-1, 0), (1, 0), (0, -1), (0, 1)]  # Up, Down, Left, Right
        for dx, dy in directions:
            new_x, new_y = x + dx, y + dy
            if 0 <= new_x < 3 and 0 <= new_y < 3:
                new_zero_pos = new_x * 3 + new_y
                new_board = self.board[:]
                # Swap zero with the neighboring tile
                new_board[self.zero_pos], new_board[new_zero_pos] = new_board[new_zero_pos],
new_board[self.zero_pos]
```

```
            neighbors.append(PuzzleState(new_board, self.g + 1))
        return neighbors

def a_star(initial_state, goal_state):
    open_set = []
    heapq.heappush(open_set, (initial_state.f(), 0, initial_state))  # Add a unique identifier (0 in this case)
    came_from = {}
    g_score = {tuple(initial_state.board): 0}

    while open_set:
        current_f, _, current = heapq.heappop(open_set)

        if current.board == goal_state:
            return reconstruct_path(came_from, current)

        for neighbor in current.get_neighbors():
            neighbor_tuple = tuple(neighbor.board)
            tentative_g_score = g_score[tuple(current.board)] + 1

            if neighbor_tuple not in g_score or tentative_g_score < g_score[neighbor_tuple]:
                came_from[neighbor_tuple] = current
                g_score[neighbor_tuple] = tentative_g_score
                heapq.heappush(open_set, (neighbor.f(), neighbor.g, neighbor))

    return None  # No solution found

def reconstruct_path(came_from, current):
    path = []
    while current is not None:
```

```
        path.append(current.board)
        current = came_from.get(tuple(current.board), None)
    return path[::-1]

# Example usage
if __name__ == "__main__":
    initial_state = PuzzleState([1, 2, 3, 4, 5, 6, 0, 7, 8])
    goal_state = [1, 2, 3, 4, 5, 6, 7, 8, 0]
    solution = a_star(initial_state, goal_state)

    if solution:
        for step in solution:
            print(step)
    else:
        print("No solution found")

    print("TARUN M M")
    print("1BM22CS306")
```

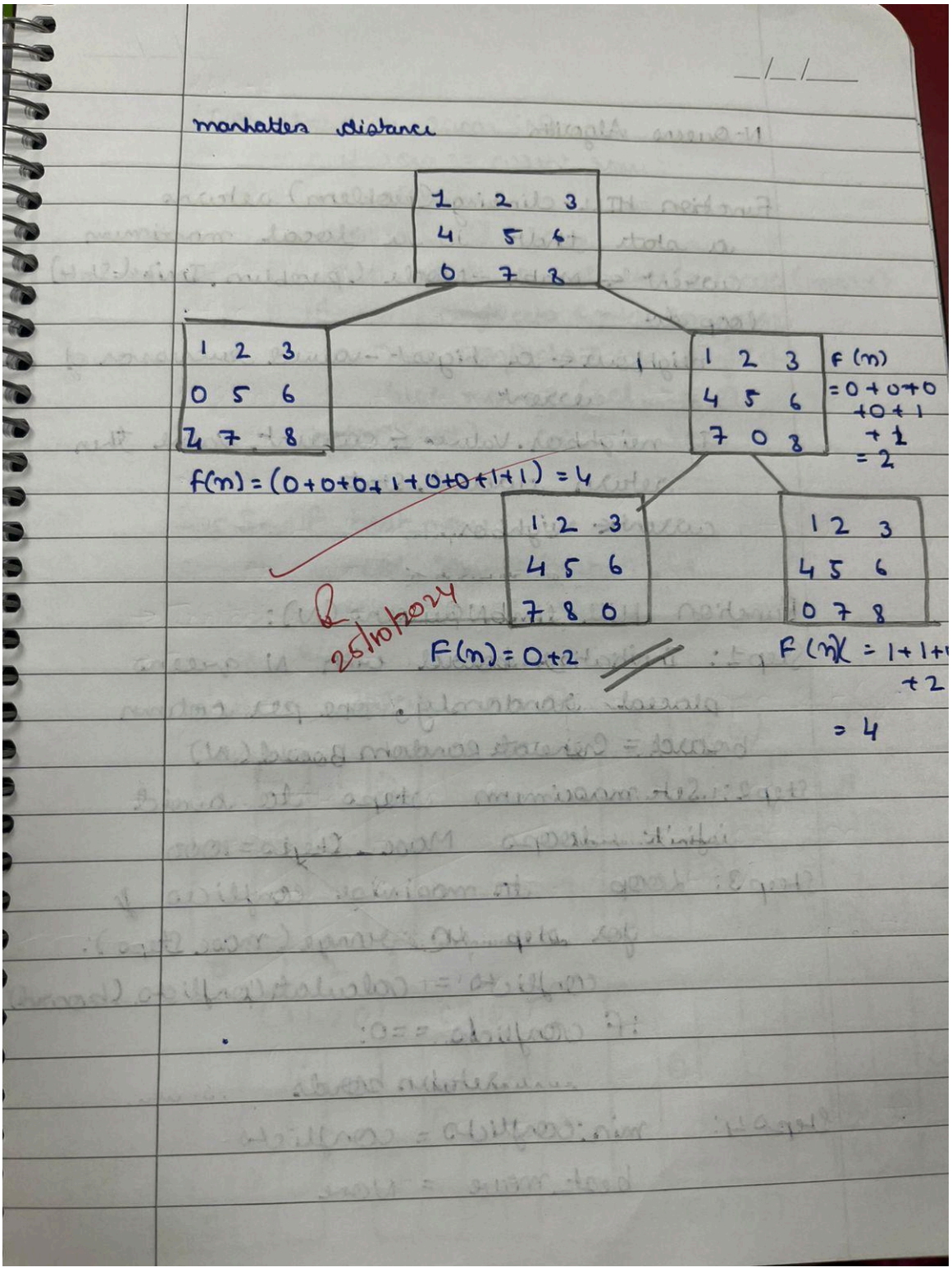
Output Snapshot

```
[1, 2, 3, 4, 5, 6, 0, 7, 8]
[1, 2, 3, 4, 5, 6, 7, 0, 8]
[1, 2, 3, 4, 5, 6, 7, 8, 0]
```

State Space Tree

__/__/____

manhatten distance



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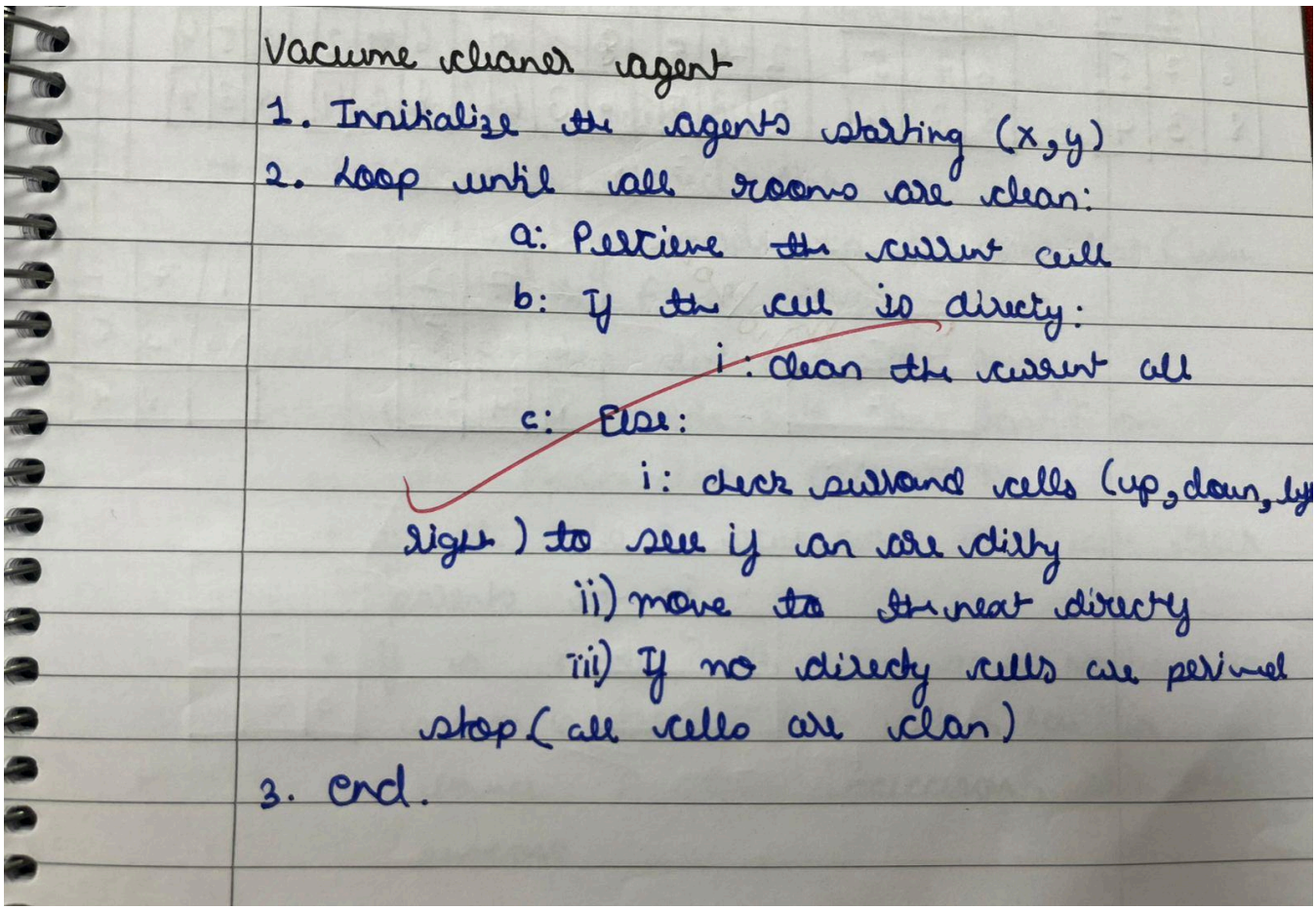
Program 4 - Vacuum Cleaner

Algorithm



Code

```
def vacuum_world():
    goal_state = {'A': '0', 'B': '0'}
    cost = 0

    location_input = input("Enter Location of Vacuum: ")
    status_input = input("Enter status of " + location_input + " (0 for Clean, 1 for Dirty): ")
    status_input_complement = input("Enter status of other room (0 for Clean, 1 for Dirty): ")

    print("Initial Location Condition: " + str(goal_state))

    if location_input == 'A':
        print("Vacuum is placed in Location A")
        if status_input == '1':
            print("Location A is Dirty.")
            goal_state['A'] = '0'
            cost += 1
            print("Cost for CLEANING A: " + str(cost))
            print("Location A has been Cleaned.")

        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving right to Location B.")
            cost += 1
            print("COST for moving RIGHT: " + str(cost))
            goal_state['B'] = '0'
            cost += 1
            print("COST for SUCK: " + str(cost))
            print("Location B has been Cleaned.")
        else:
            print("No action needed; Location B is already clean.")
    else:
        print("Location A is already clean.")
        if status_input_complement == '1':
            print("Location B is Dirty.")
            print("Moving RIGHT to Location B.")
```

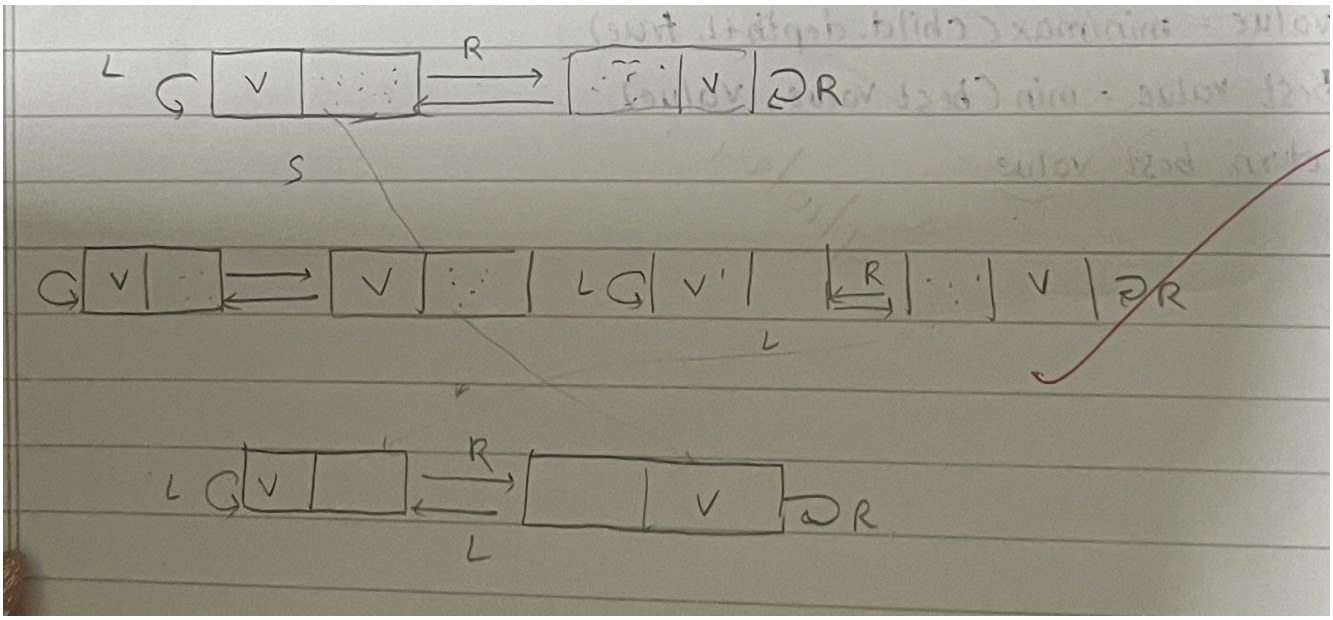
```
        cost += 1
        print("COST for moving RIGHT: " + str(cost))
        goal_state['B'] = '0'
        cost += 1
        print("COST for SUCK: " + str(cost))
        print("Location B has been Cleaned.")
    else:
        print("No action needed; Location B is already clean.")

if location_input == 'B':
    print("Vacuum is placed in Location B")
    if status_input == '1':
        print("Location B is Dirty.")
        goal_state['B'] = '0'
        cost += 1
        print("COST for CLEANING B: " + str(cost))
        print("Location B has been Cleaned.")

    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to Location A.")
        cost += 1
        print("COST for moving LEFT: " + str(cost))
        goal_state['A'] = '0'
        cost += 1
        print("COST for SUCK: " + str(cost))
        print("Location A has been Cleaned.")
    else:
        print("No action needed; Location A is already clean.")
else:
    print("Location B is already clean.")
    if status_input_complement == '1':
        print("Location A is Dirty.")
        print("Moving LEFT to Location A.")
        cost += 1
        print("COST for moving LEFT: " + str(cost))
```

```
        goal_state['A'] = '0'
        cost += 1
        print("COST for SUCK: " + str(cost))
        print("Location A has been Cleaned.")
    else:
        print("No action needed; Location A is already clean.")

print("GOAL STATE: ")
print(goal_state)
print("Performance Measurement: " + str(cost))
print("TARUN M M ")
print("1BM22CS306")

vacuum_world()
```

Output Snapshot

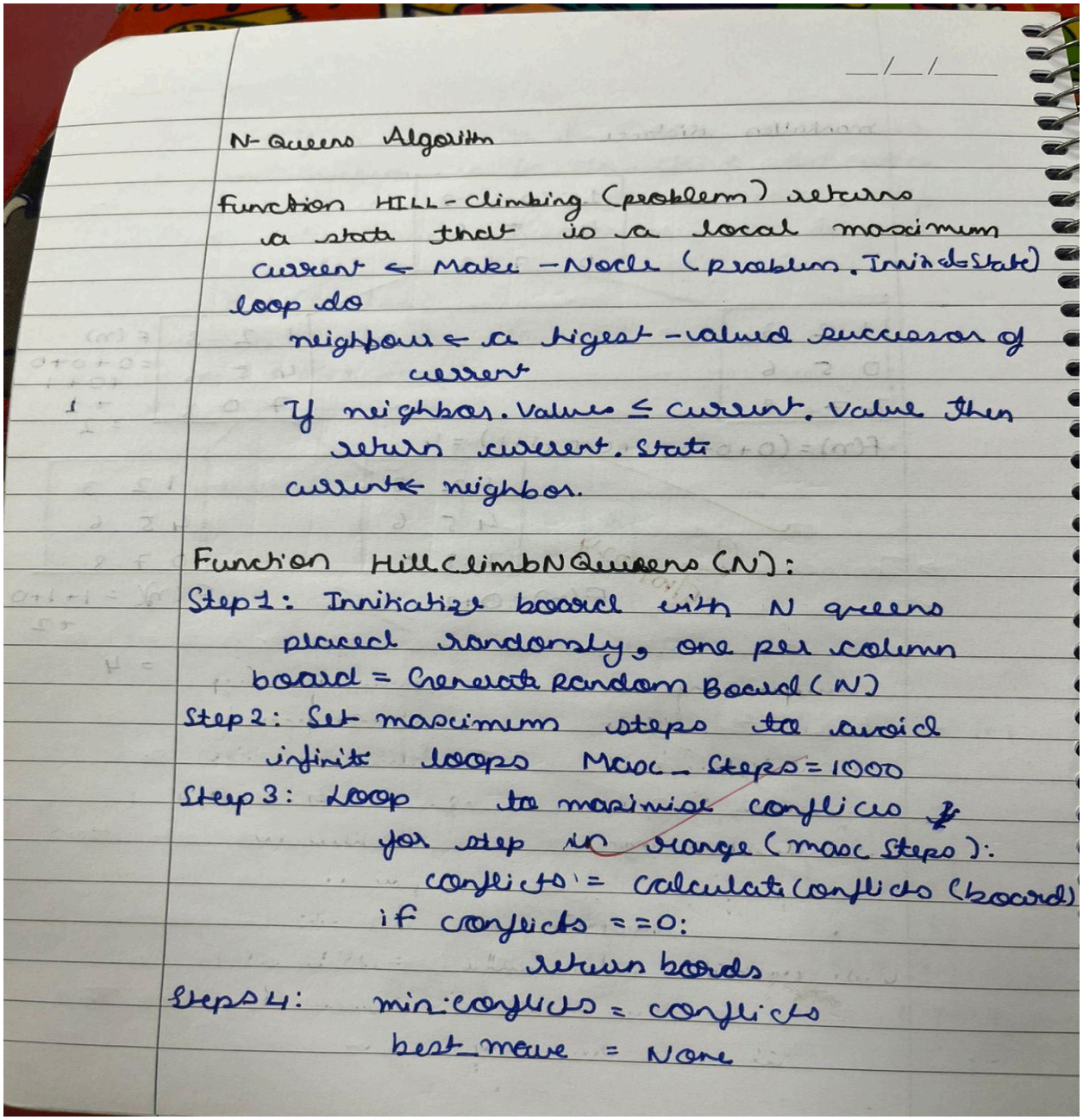
```
Enter Location of Vacuum: 3
Enter status of 3 (0 for Clean, 1 for Dirty): 1
Enter status of other room (0 for Clean, 1 for Dirty): 0
Initial Location Condition: {'A': '0', 'B': '0'}
Location A is already clean.
No action needed; Location B is already clean.
Location B is already clean.
No action needed; Location A is already clean.
GOAL STATE:
{'A': '0', 'B': '0'}
Performance Measurement: 0
```

State Space Tree



Program-05 Hill Climbing

Algorithm



N-Queens Algorithm

function HILL-climbing (problem) returns a state that is a local maximum
current ← Make-Node (problem.InitialState)
loop do
neighbour ← a higest-valued successor of current
If neighbor.Value ≤ current.Value then return current.State
current ← neighbor.

Function HillClimbNQueens(N):
Step 1: Initialize board with N queens placed randomly, one per column
board = GenerateRandomBoard(N)
Step 2: Set maximum steps to avoid infinite loops Max_Steps = 1000
Step 3: Loop to minimize conflicts
for step in range(max_Steps):
conflicts = calculateConflicts(board)
if conflicts == 0:
return board
Steps 4: min_conflicts = conflicts
best_move = None

Code

```
import random

def print_board(board, n):
    """Prints the current state of the board."""
    for row in range(n):
        line = ""
        for col in range(n):
            if board[col] == row:
                line += " Q "
            else:
                line += " . "
        print(line)
    print()

def calculate_conflicts(board, n):
    """Calculates the number of conflicts (attacks) between queens."""
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check if queens are in the same row or diagonal
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def get_best_neighbor(board, n):
    """
    Finds the best neighboring board with the fewest conflicts.
    Returns the best board and its conflict count.
    """
    current_conflicts = calculate_conflicts(board, n)
    best_board = board[:]
    best_conflicts = current_conflicts
    neighbors = []
```

```
    for col in range(n):
        original_row = board[col]
        for row in range(n):
            if row == original_row:
                continue
            # Move queen to a new row and calculate conflicts
            board[col] = row
            new_conflicts = calculate_conflicts(board, n)
            neighbors.append((board[:], new_conflicts))
        # Restore the original row before moving to the next column
        board[col] = original_row

    # Sort neighbors by the number of conflicts (ascending)
    neighbors.sort(key=lambda x: x[1])
    if neighbors:
        best_neighbor = neighbors[0]
        if best_neighbor[1] < best_conflicts:
            return best_neighbor
    return board, current_conflicts

def hill_climbing_with_restarts(n, initial_board, max_restarts=100):
    """
    Performs Hill Climbing with random restarts to solve the N-Queens problem.
    Returns the final board configuration and its conflict count.
    """
    current_board = initial_board[:]
    current_conflicts = calculate_conflicts(current_board, n)

    print("Initial board:")
    print_board(current_board, n)
    print(f"Initial conflicts: {current_conflicts}\n")

    steps = 0
    restarts = 0
```

```
    while current_conflicts > 0 and restarts < max_restarts:
        new_board, new_conflicts = get_best_neighbor(current_board, n)

        steps += 1
        print(f"Step {steps}:")
        print_board(new_board, n)
        print(f"Conflicts: {new_conflicts}\n")

        if new_conflicts < current_conflicts:
            current_board = new_board
            current_conflicts = new_conflicts
        else:
            # If no better neighbor is found, perform a random restart
            restarts += 1
            print(f"Restarting... (Restart number {restarts})\n")
            current_board = [random.randint(0, n-1) for _ in range(n)]
            current_conflicts = calculate_conflicts(current_board, n)
            print("New initial board:")
            print_board(current_board, n)
            print(f"Conflicts: {current_conflicts}\n")

    return current_board, current_conflicts

# Main function
def main():
    n = 4
    print("Enter the initial positions of queens (row numbers from 0 to 3 for each column):")
    initial_board = []
    for i in range(n):
        while True:
            try:
                row = int(input(f"Column {i}: "))
                if 0 <= row < n:
                    initial_board.append(row)
                    break
                else:
```

```
                print(f"Please enter a number between 0 and {n-1}.")
            except ValueError:
                print("Invalid input. Please enter an integer.")

    solution, conflicts = hill_climbing_with_restarts(n, initial_board)

    print("Final solution:")
    print_board(solution, n)
    if conflicts == 0:
        print("A solution was found with no conflicts!")
    else:
        print(f"No solution was found after {100} restarts. Final number of conflicts: {conflicts}")

if __name__ == "__main__":
    main()
print("TARUN M M")
print("1BM22CS306")
```

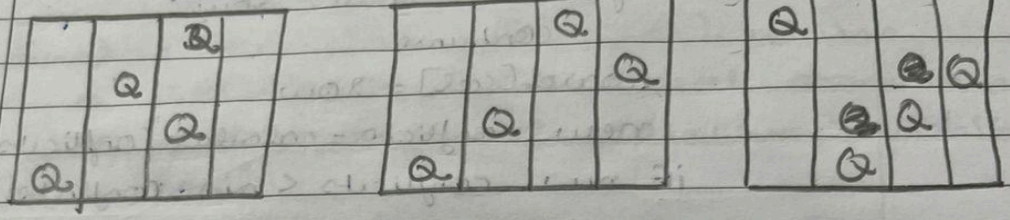
OUTPUT

```
Step 5:
 Q  .  .  .
 .  .  .  .
 .  .  .  Q
 .  Q  Q  .

Conflicts: 2

Step 6:
 Q  .  Q  .
 .  .  .  .
 .  .  .  Q
 .  Q  .  .

Conflicts: 1

Step 7:
 .  .  Q  .
 Q  .  .  .
 .  .  .  Q
 .  Q  .  .

Conflicts: 0

Final solution:
 .  .  Q  .
 Q  .  .  .
 .  .  .  Q
 .  Q  .  .

A solution was found with no conflicts!
```

State Space Tree

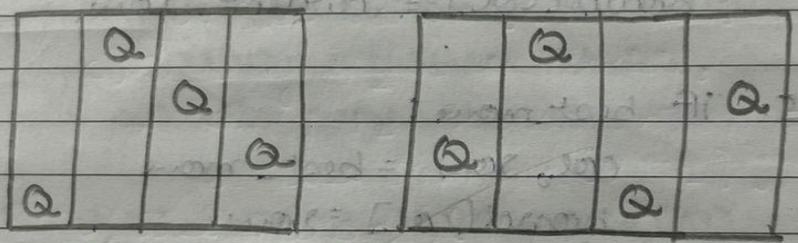
__/__/____

(1320) 2310 0321
(3120)



(1230)

1302

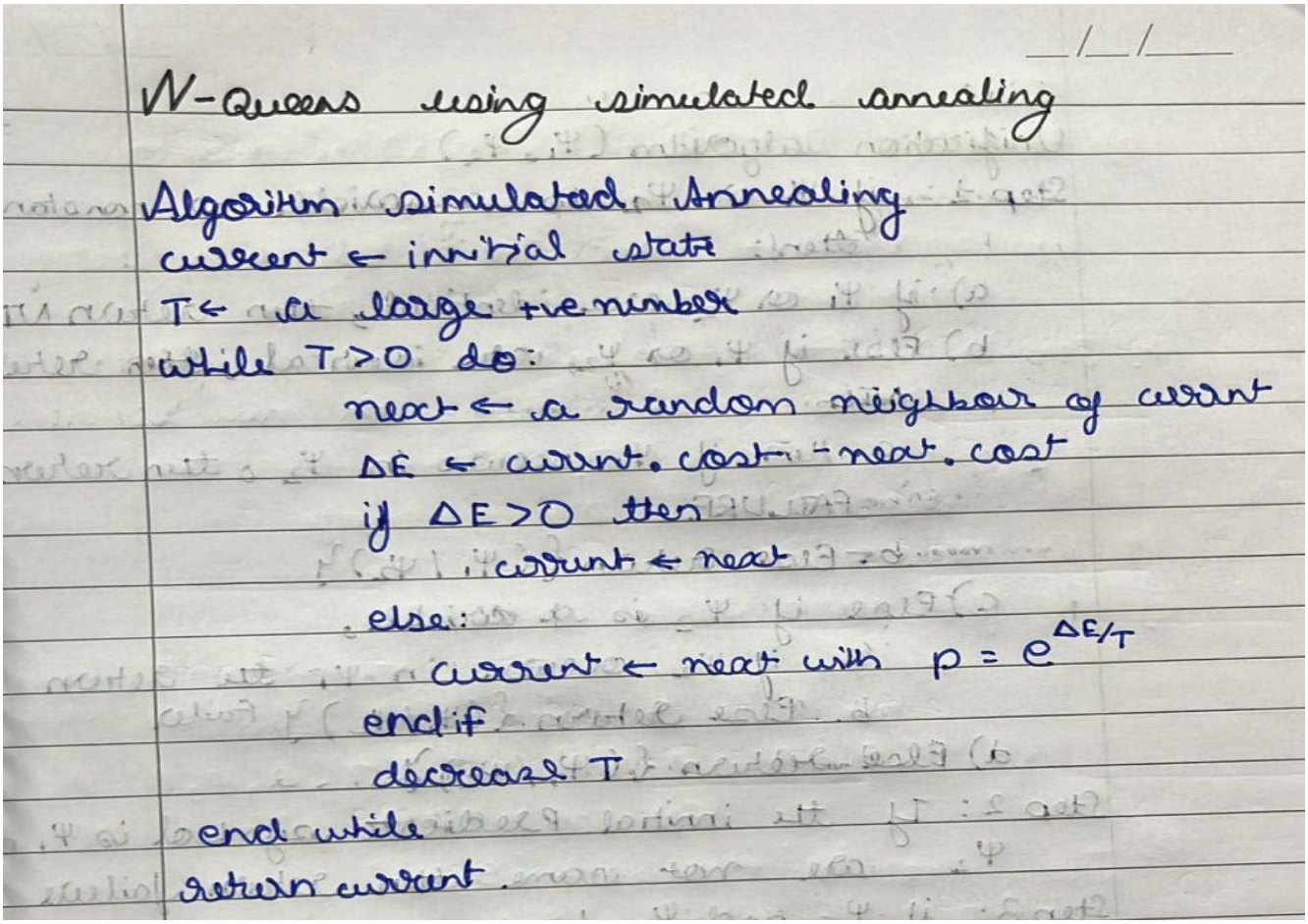


Solution

15/11/24.

Program-06 Simulated Annealing

Algorithm



N-Queens using simulated annealing

Algorithm simulated Annealing
current ← initial state
T ← a large +ve number
while T > 0 do:
    next ← a random neighbour of current
    ΔE ← current.cost - next.cost
    if ΔE > 0 then
        current ← next
    else:
        current ← next with $p = e^{\Delta E/T}$
    endif
    decrease T
end while
return current

Code

```
import random
import math
```

```
def print_board(board, n):
    """Prints the current state of the board."""
    for row in range(n):
        line = ""
        for col in range(n):
            if board[col] == row:
                line += " Q "  # Queen is represented by "Q"
            else:
                line += " . "  # Empty space represented by "."
        print(line)
    print()

def calculate_conflicts(board, n):
    """Calculates the number of conflicts (attacks) between queens."""
    conflicts = 0
    for i in range(n):
        for j in range(i + 1, n):
            # Check if queens are in the same row or diagonal
            if board[i] == board[j] or abs(board[i] - board[j]) == abs(i - j):
                conflicts += 1
    return conflicts

def simulated_annealing(n, initial_temp=1000, cooling_rate=0.995, max_iterations=10000):
    """Simulated Annealing algorithm to solve N-Queens with detailed steps."""
    # Initial random board configuration (one queen in each column)
    board = [random.randint(0, n - 1) for _ in range(n)]
    current_conflicts = calculate_conflicts(board, n)
    temperature = initial_temp
    iteration = 0

    print("Initial board:")
    print_board(board, n)
    print(f"Initial conflicts: {current_conflicts}\n")

    while current_conflicts > 0 and iteration < max_iterations:
        # Generate a neighboring state by moving a queen to another row in its column
```

```
        col = random.randint(0, n - 1)
        original_row = board[col]
        new_row = random.randint(0, n - 1)
        while new_row == original_row:
            new_row = random.randint(0, n - 1)  # Ensure we are moving the queen to a new row
        board[col] = new_row

        # Calculate the number of conflicts in the new configuration
        new_conflicts = calculate_conflicts(board, n)

        # Display the current step, board, and conflicts
        print(f"Iteration {iteration + 1}:")
        print(f"Temperature: {temperature:.2f}")
        print(f"Trying to move queen in column {col} from row {original_row} to row {new_row}")
        print_board(board, n)
        print(f"New conflicts: {new_conflicts}, Current conflicts: {current_conflicts}")

        # If the new state has fewer conflicts, accept it.
        # If the new state has more conflicts, accept it with a certain probability.
        if new_conflicts < current_conflicts or random.random() < math.exp((current_conflicts -
new_conflicts) / temperature):
            current_conflicts = new_conflicts
            print("Move accepted.\n")
        else:
            # If no improvement, revert the move
            board[col] = original_row
            print("Move rejected. Reverting to previous state.\n")

        # Reduce the temperature according to the cooling schedule
        temperature *= cooling_rate

        iteration += 1

    return board, current_conflicts

def main():
```

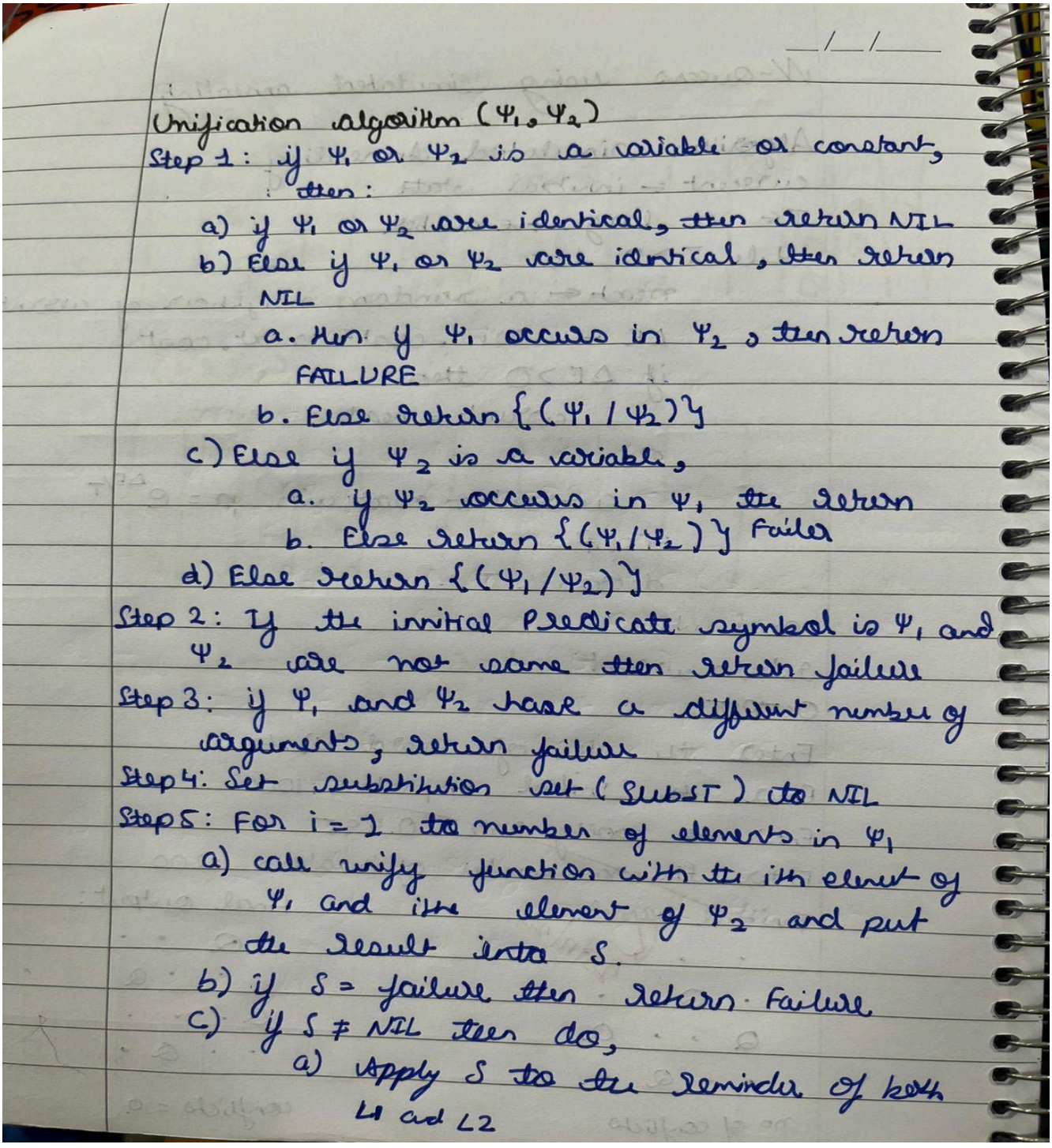
```
    # Input dynamic parameters
    print("Welcome to the N-Queens Problem Solver using Simulated Annealing!")
    n = int(input("Enter the size of the board (N): "))
    initial_temp = float(input("Enter the initial temperature (e.g., 1000): "))
    cooling_rate = float(input("Enter the cooling rate (e.g., 0.995): "))
    max_iterations = int(input("Enter the maximum number of iterations (e.g., 10000): "))
    print("TARUN M M ")
    print("1BM22CS306")

    solution, conflicts = simulated_annealing(n, initial_temp, cooling_rate, max_iterations)

    print("Final solution:")
    print_board(solution, n)
    if conflicts == 0:
        print("A solution was found with no conflicts!")
    else:
        print(f"No solution was found after {max_iterations} iterations. Final number of conflicts:
{conflicts}")

if __name__ == "__main__":
    main()
```

Output Snapshot

```
Welcome to the N-Queens Problem Solver using Simulated Annealing!
Enter the size of the board (N): 4
Enter the initial temperature (e.g., 1000): 1000
Enter the cooling rate (e.g., 0.995): 0.995
Enter the maximum number of iterations (e.g., 10000): 200
Initial board:
 .  .  .  .
 .  Q  .  .
 Q  .  .  Q
 .  .  Q  .

Initial conflicts: 3

Final solution:
 .  Q  .  .
 .  .  .  Q
 Q  .  .  .
 .  .  Q  .

A solution was found with no conflicts!
```

Program-07 Unification in first order logic

Algorithm



Unification algorithm (Ψ_1, Ψ_2)

Step 1: if Ψ_1 or Ψ_2 is a variable or constant, then:

a) if Ψ_1 or Ψ_2 are identical, then return NIL

b) Else if Ψ_1 or Ψ_2 are identical, then return NIL

a. Then if Ψ_1 occurs in Ψ_2, then return FAILURE

b. Else return $\{(\Psi_1 / \Psi_2)\}$

c) Else if Ψ_2 is a variable,

a. if Ψ_2 occurs in Ψ_1 the return

b. Else return $\{(\Psi_1 / \Psi_2)\}$ Failed

d) Else return $\{(\Psi_1 / \Psi_2)\}$

Step 2: If the initial Predicate symbol is Ψ_1 and Ψ_2 are not same then return failure

Step 3: if Ψ_1 and Ψ_2 have a different number of arguments, return failure

Step 4: Set substitution set (SUBST) to NIL

Step 5: For i = 1 to number of elements in Ψ_1

a) call unify function with the ith element of Ψ_1 and ith element of Ψ_2 and put the result into S.

b) if S = failure then return Failure

c) if S ≠ NIL then do,

a) Apply S to the remainder of both L1 and L2

Code

```
import ast
from typing import Union, List, Dict, Tuple
from collections import deque

# Define Term Classes
class Term:
    def substitute(self, subs: Dict[str, 'Term']) -> 'Term':
        raise NotImplementedError

    def occurs(self, var: 'Variable') -> bool:
        raise NotImplementedError

    def __eq__(self, other):
        raise NotImplementedError

    def __str__(self):
        raise NotImplementedError

class Variable(Term):
    def __init__(self, name: str):
        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:
        if self.name in subs:
            return subs[self.name].substitute(subs)
        return self

    def occurs(self, var: 'Variable') -> bool:
        return self.name == var.name

    def __eq__(self, other):
        return isinstance(other, Variable) and self.name == other.name

    def __str__(self):
        return self.name
```

```
class Constant(Term):
    def __init__(self, name: str):
        self.name = name

    def substitute(self, subs: Dict[str, Term]) -> Term:
        return self

    def occurs(self, var: 'Variable') -> bool:
        return False

    def __eq__(self, other):
        return isinstance(other, Constant) and self.name == other.name

    def __str__(self):
        return self.name

class Function(Term):
    def __init__(self, name: str, args: List[Term]):
        self.name = name
        self.args = args

    def substitute(self, subs: Dict[str, Term]) -> Term:
        substituted_args = [arg.substitute(subs) for arg in self.args]
        return Function(self.name, substituted_args)

    def occurs(self, var: 'Variable') -> bool:
        return any(arg.occurs(var) for arg in self.args)

    def __eq__(self, other):
        return (
            isinstance(other, Function) and
            self.name == other.name and
            len(self.args) == len(other.args) and
            all(a == b for a, b in zip(self.args, other.args))
        )
```

```
    def __str__(self):
        return f"{self.name}({', '.join(str(arg) for arg in self.args)})"

def parse_expression(expr: List) -> Term:
    if not isinstance(expr, list) or not expr:
        raise ValueError("Expression must be a non-empty list")

    func_name = expr[0]
    args = expr[1:]

    parsed_args = []
    for arg in args:
        if isinstance(arg, list):
            parsed_args.append(parse_expression(arg))
        elif isinstance(arg, str):
            if arg[0].islower():
                parsed_args.append(Variable(arg))
            elif arg[0].isupper():
                parsed_args.append(Constant(arg))
            else:
                raise ValueError(f"Invalid argument format: {arg}")
        else:
            raise ValueError(f"Unsupported argument type: {arg}")

    return Function(func_name, parsed_args)

def unify_terms(term1: Term, term2: Term) -> Union[Dict[str, Term], str]:
    # Initialize substitution set S
    S: Dict[str, Term] = {}

    # Initialize the equation list
    equations: deque[Tuple[Term, Term]] = deque()
    equations.append((term1, term2))

    while equations:
        s, t = equations.popleft()
```

```
        s = s.substitute(S)
        t = t.substitute(S)

        if s == t:
            continue
        elif isinstance(s, Variable):
            if t.occurs(s):
                return "FAILURE"
            S[s.name] = t
            # Apply the substitution to existing substitutions
            for var in S:
                S[var] = S[var].substitute({s.name: t})
        elif isinstance(t, Variable):
            if s.occurs(t):
                return "FAILURE"
            S[t.name] = s
            for var in S:
                S[var] = S[var].substitute({t.name: s})
        elif isinstance(s, Function) and isinstance(t, Function):
            if s.name != t.name or len(s.args) != len(t.args):
                return "FAILURE"
            for s_arg, t_arg in zip(s.args, t.args):
                equations.append((s_arg, t_arg))
        elif isinstance(s, Constant) and isinstance(t, Constant):
            if s.name != t.name:
                return "FAILURE"
            # else, they are equal; continue
        else:
            return "FAILURE"

    return S

def format_substitution(S: Dict[str, Term]) -> str:
    if not S:
        return "{}"
    return "{ " + ", ".join(f"{var} = {term}" for var, term in S.items()) + " }"
```

```
def unify(expression1: List, expression2: List) -> Union[Dict[str, Term], str]:
    try:
        term1 = parse_expression(expression1)
        term2 = parse_expression(expression2)
    except ValueError as e:
        return f"FAILURE: {e}"

    result = unify_terms(term1, term2)

    return result

def main():
    print("=== Unification Algorithm ===\n")
    print("Please enter the expressions in list format.")
    print("Example: [\"Eats\", \"x\", \"Apple\"]\n")

    try:
        expr1_input = input("Enter Expression 1: ")
        expression1 = ast.literal_eval(expr1_input)
        if not isinstance(expression1, list):
            raise ValueError("Expression must be a list.")

        expr2_input = input("Enter Expression 2: ")
        expression2 = ast.literal_eval(expr2_input)
        if not isinstance(expression2, list):
            raise ValueError("Expression must be a list.")

    except (SyntaxError, ValueError) as e:
        print(f"Invalid input format: {e}")
        return

    result = unify(expression1, expression2)

    if isinstance(result, str):
        print("\nUnification Result:")
```

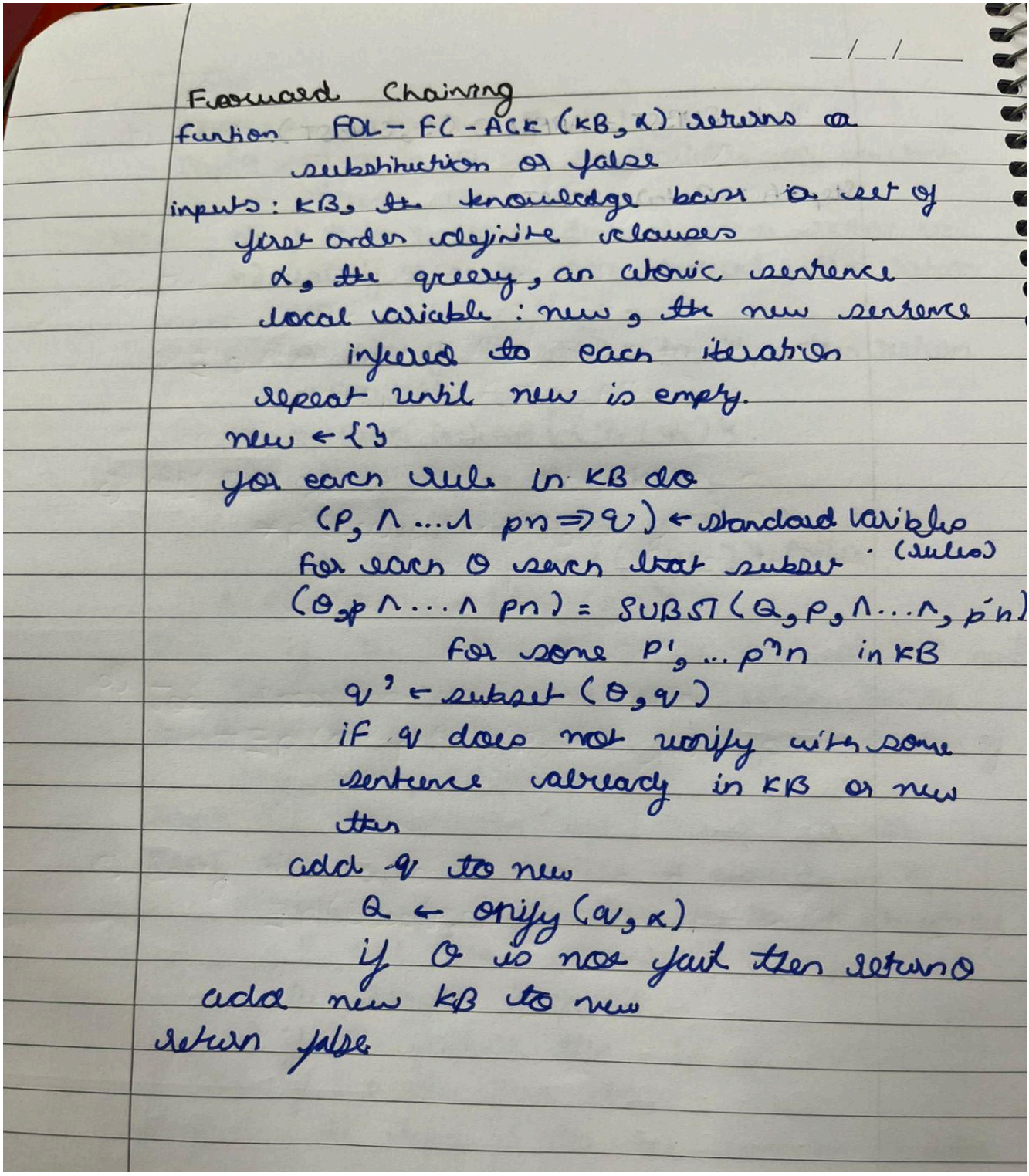
```
        print(result)
    else:
        print("\nUnification Successful:")
        print(format_substitution(result))

if __name__ == "__main__":
    main()
print("TARUN M M")
print("1BM22CS306 \n")
```

Output Snapshot

```
=== Unification Algorithm ===

Please enter the expressions in list format.
Example: ["Eats", "x", "Apple"]

Enter Expression 1: ["Eats", "x", "Apple"]
Enter Expression 2: ["Eats", "bananna ", "y"]

Unification Successful:
{ x = bananna , y = Apple }
```

Program-8 Forward Reasoning

Algorithm



Forward Chaining

function FOL-FC-ASK(KB, α) returns a substitution or false

inputs: KB, the knowledge base, a set of first order definite clauses

α, the query, an atomic sentence

local variable: new, the new sentence inferred in each iteration

repeat until new is empty.

new ← {}

for each rule in KB do

(p1 ∧ ... ∧ pn ⇒ q) ← Standard Variables

for each θ such that subset (rules)

(θp1 ∧ ... ∧ pn) = SUBST(θ, p1 ∧ ... ∧ p'n)

for some p'1, ... p'n in KB

q' ← subset(θ, q)

if q does not unify with some sentence already in KB or new

then

add q to new

θ ← unify(q, α)

if θ is not fail then return θ

add new KB to new

return false

Code

```
def fol_fc_ask(KB, query):
    """
    Implements the Forward Chaining algorithm.
    :param KB: The knowledge base, a list of first-order definite clauses.
    :param query: The query, an atomic sentence.
    :return: True if the query can be proven, otherwise False.
    """
    inferred = set()  # Keep track of inferred facts
    agenda = [fact for fact in KB if not fact.get('premises')]  # Initial facts
    rules = [rule for rule in KB if rule.get('premises')]  # Rules with premises

    # Debugging output: Initial agenda and inferred facts
    print(f"Initial agenda: {[fact['conclusion'] for fact in agenda]}")
    print(f"Initial inferred: {inferred}")

    while agenda:
        fact = agenda.pop(0)
```

```
print(f"\nProcessing fact: {fact['conclusion']}")


# Check if this fact matches the query
if fact['conclusion'] == query:
    print(f"Found query match: {fact['conclusion']}")
    return True


# Infer new facts if this fact hasn't been inferred before
if fact['conclusion'] not in inferred:
    inferred.add(fact['conclusion'])
    print(f"Inferred facts: {inferred}")


    # Process rules that match this fact as a premise
    for rule in rules:
        if fact['conclusion'] in rule['premises']:
            print(f"Rule premise satisfied: {rule['premises']} -> {rule['conclusion']}")
            rule['premises'].remove(fact['conclusion'])  # Remove satisfied premise
            if not rule['premises']:  # All premises satisfied
                new_fact = {'conclusion': rule['conclusion']}
                agenda.append(new_fact)  # Add new fact to agenda
```

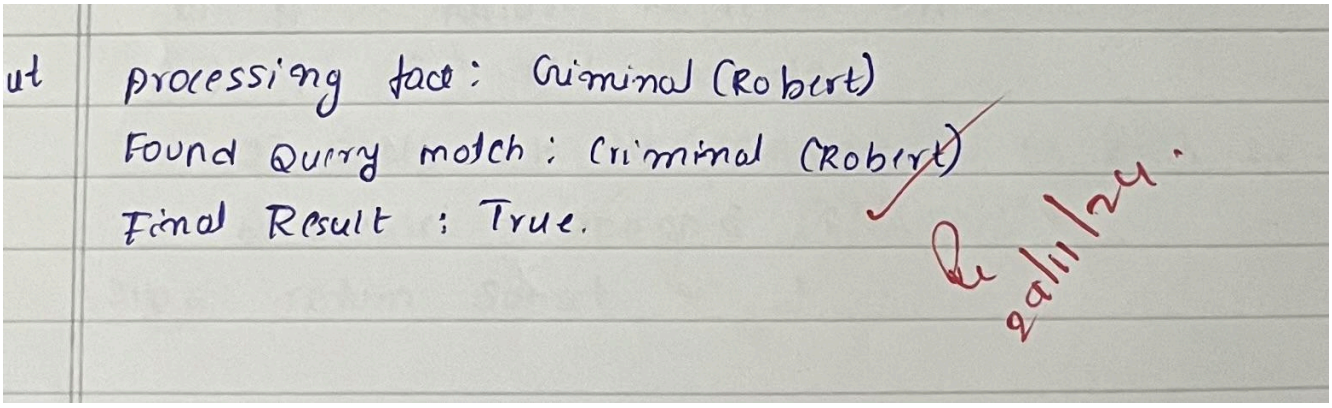
```
                print(f"New fact inferred: {new_fact['conclusion']}")


        # Debugging output after each iteration
        print(f"Current agenda: {[fact['conclusion'] for fact in agenda]}")
        print(f"Current inferred: {inferred}")


    # If the loop finishes without finding the query
    print(f"Query {query} not found.")
    return False



# Example Knowledge Base
KB = [
    {'premises': [], 'conclusion': 'American(Robert)'},
    {'premises': [], 'conclusion': 'Missile(T1)'},
    {'premises': [], 'conclusion': 'Owns(A, T1)'},
    {'premises': [], 'conclusion': 'Enemy(A, America)'},
    {'premises': ['Missile(T1)'], 'conclusion': 'Weapon(T1)'},
    {'premises': ['American(Robert)', 'Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'], 'conclusion':
'Criminal(Robert)'},
    {'premises': ['Owns(A, T1)', 'Enemy(A, America)'], 'conclusion': 'Hostile(A)'},
```

```
    {'premises': [], 'conclusion': 'Sells(Robert, T1, A)'}

]



# Query

query = 'Criminal(Robert)'



# Run the algorithm

result = fol_fc_ask(KB, query)

print("Final Result:", result)

print("TARUN M M")

print("1BM22CS306")
```

OutputSnapshot

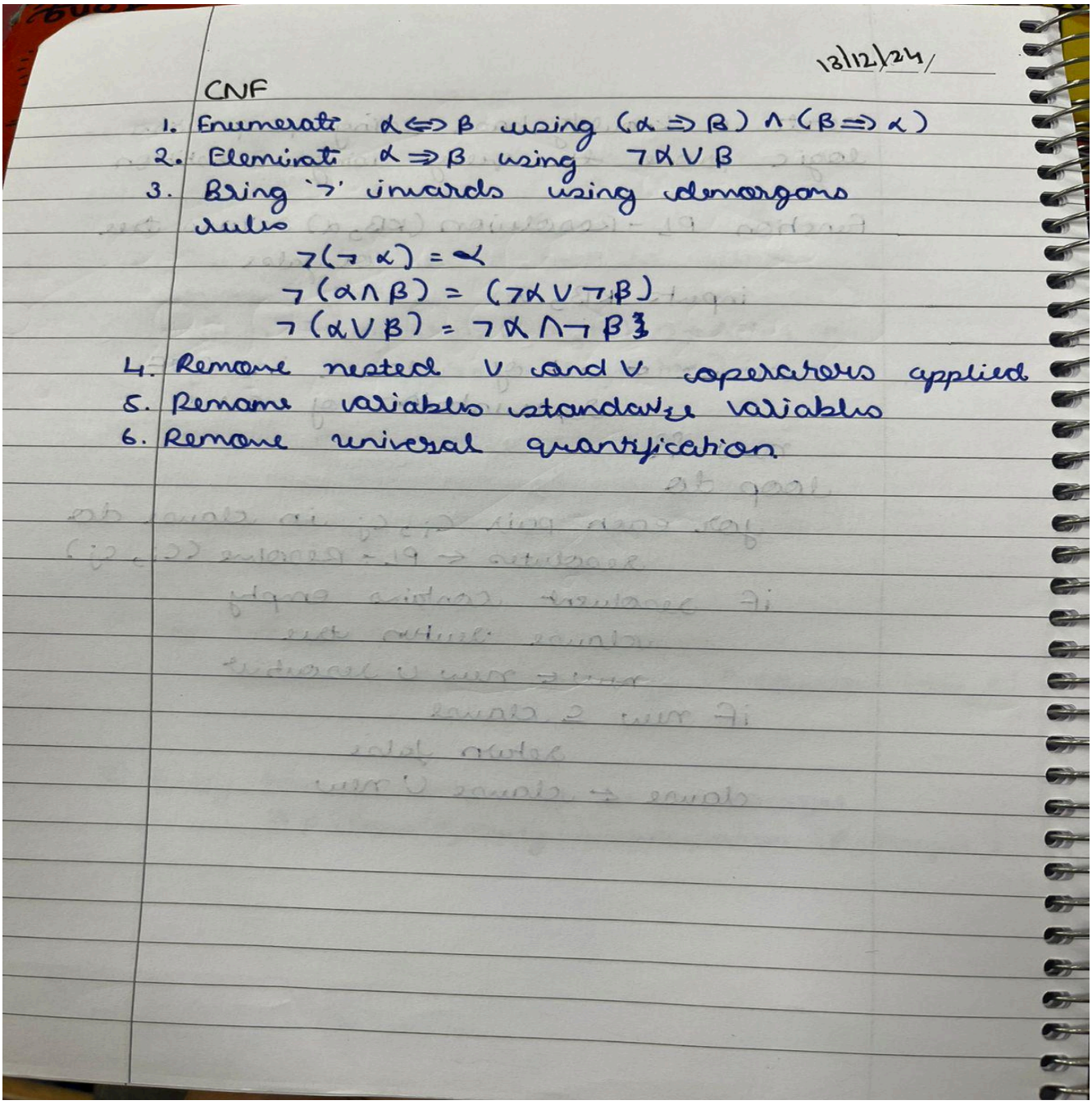
```
Processing fact: Enemy(A, America)
Inferred facts: {'Missile(T1)', 'Enemy(A, America)', 'Owns(A, T1)', 'American(Robert)'}
Rule premise satisfied: ['Enemy(A, America)'] -> Hostile(A)
New fact inferred: Hostile(A)
Current agenda: ['Sells(Robert, T1, A)', 'Weapon(T1)', 'Hostile(A)']
Current inferred: {'Missile(T1)', 'Enemy(A, America)', 'Owns(A, T1)', 'American(Robert)'}

Processing fact: Sells(Robert, T1, A)
Inferred facts: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'American(Robert)'}
Rule premise satisfied: ['Weapon(T1)', 'Sells(Robert, T1, A)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Weapon(T1)', 'Hostile(A)']
Current inferred: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'American(Robert)'}

Processing fact: Weapon(T1)
Inferred facts: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}
Rule premise satisfied: ['Weapon(T1)', 'Hostile(A)'] -> Criminal(Robert)
Current agenda: ['Hostile(A)']
Current inferred: {'Enemy(A, America)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}

Processing fact: Hostile(A)
Inferred facts: {'Enemy(A, America)', 'Hostile(A)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}
Rule premise satisfied: ['Hostile(A)'] -> Criminal(Robert)
New fact inferred: Criminal(Robert)
Current agenda: ['Criminal(Robert)']
Current inferred: {'Enemy(A, America)', 'Hostile(A)', 'Owns(A, T1)', 'Missile(T1)', 'Sells(Robert, T1, A)', 'Weapon(T1)', 'American(Robert)'}

Processing fact: Criminal(Robert)
Found query match: Criminal(Robert)
Final Result: True
```

State Space Tree



Program - 9 Create a knowledge base using propositional logic and show that the given query entails the knowledge base or not.

Algorithm



13/12/24

CNF

1. Enumerate $\alpha \Leftrightarrow \beta$ using $(\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)$
2. Eliminate $\alpha \Rightarrow \beta$ using $\neg\alpha \vee \beta$
3. Bring '¬' inwards using demorgans rule

$\neg(\neg\alpha) = \alpha$

$\neg(\alpha \wedge \beta) = (\neg\alpha \vee \neg\beta)$

$\neg(\alpha \vee \beta) = \neg\alpha \wedge \neg\beta$

4. Remove nested $\wedge$ and $\vee$ operators applied
5. Rename variables standardize variables
6. Remove universal quantification

Code

```
combinations = [
  (True, True, True), (True, True, False), (True, False, True), (True, False, False),
  (False, True, True), (False, True, False), (False, False, True), (False, False, False)
]

variable = {'p': 0, 'q': 1, 'r': 2}
kb = ''
q = ''
priority = {'~': 3, 'v': 1, '^': 2}

def input_rules():
  global kb, q
  kb = input("Enter rule: ")  # Knowledge Base (KB)
  q = input("Enter the Query: ")  # Query

def entailment():
  global kb, q
  print('*' * 10 + "Truth Table Reference" + '*' * 10)
  print('kb', 'alpha')
  print('*' * 10)

  for comb in combinations:
    s = evaluatePostfix(toPostfix(kb), comb)  # Evaluate KB
    f = evaluatePostfix(toPostfix(q), comb)  # Evaluate Query
    print(s, f)
    print('-' * 10)

    if s and not f:  # If KB is True and query is False, KB does not entail query
      return False
  return True

def isOperand(c):
```

```
  return c.isalpha() and c != 'v'

def isLeftParanthesis(c):
  return c == '('

def isRightParanthesis(c):
  return c == ')'

def isEmpty(stack):
  return len(stack) == 0

def peek(stack):
  return stack[-1]

def hasLessOrEqualPriority(c1, c2):
  try:
    return priority[c1] <= priority[c2]
  except KeyError:
    return False

def toPostfix(infix):
  stack = []
  postfix = ''

  for c in infix:
    if isOperand(c):
      postfix += c
    else:
      if isLeftParanthesis(c):
        stack.append(c)
      elif isRightParanthesis(c):
        operator = stack.pop()
        while not isLeftParanthesis(operator):
          postfix += operator
          operator = stack.pop()
      else:
        while (not isEmpty(stack)) and hasLessOrEqualPriority(c, peek(stack)):
          postfix += stack.pop()
```

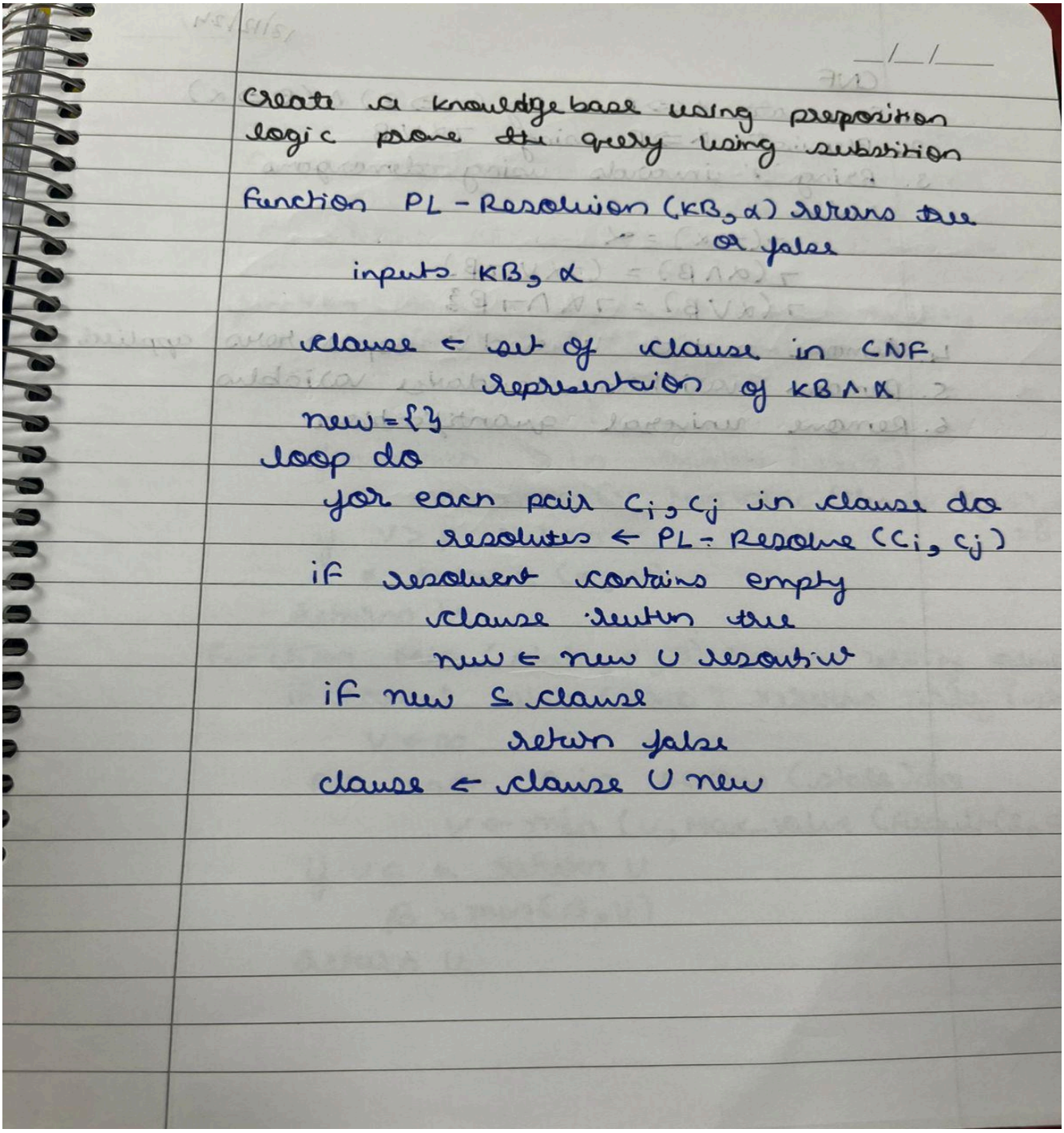
```
            stack.append(c)

    while not isEmpty(stack):
        postfix += stack.pop()

    return postfix

def evaluatePostfix(exp, comb):
    stack = []
    for i in exp:
        if isOperand(i):
            stack.append(comb[variable[i]])  # Push the truth value from the combination
        elif i == '~':
            val1 = stack.pop()
            stack.append(not val1)  # Negation
        else:
            val1 = stack.pop()
            val2 = stack.pop()
            stack.append(_eval(i, val2, val1))  # Evaluate AND or OR
    return stack.pop()

def _eval(i, val1, val2):
    if i == '^':
        return val2 and val1  # AND
    return val2 or val1  # OR

# Main Program
input_rules()
ans = entailment()

print("TARUN MM")
print("1BM22CS306")

if ans:
    print("The Knowledge Base entails the query")
else:
    print("The Knowledge Base does not entail the query")
```

OutputSnapshot

```
Enter rule: (p^q)vr
Enter the Query: p
**********Truth Table Reference**********
kb alpha
**********
True True
----------
True True
----------
True True
----------
False True
----------
True False
----------
```

Program - 10 Write a proof tree generated using Resolution

Algorithm



Create a knowledge base using preposition logic prove the query using resolution

function PL - Resolution (KB, α) returns true or false

inputs KB, α

clause ← set of clause in CNF representation of KB ∧ α

new = {}

loop do

for each pair C_i, C_j in clause do

resolutes ← PL - Resolve (C_i, C_j)

if resolvent contains empty clause return true

new ← new ∪ resolvent

if new ⊆ clause

return false

clause ← clause ∪ new

Code

```
# Helper function to negate a literal
def negate(literal):
  """Return the negation of a literal."""
  if isinstance(literal, tuple) and literal[0] == "not":
    return literal[1]
  else:
    return ("not", literal)

# Function to resolve two clauses
def resolve(clause1, clause2):
  """Return the resolvent of two clauses."""
  resolvents = set()
  for literal1 in clause1:
    for literal2 in clause2:
      if literal1 == negate(literal2):
        resolvent = (clause1 - {literal1}) | (clause2 - {literal2})
        print(f"  Resolving literal: {literal1} with {literal2}")
        print(f"  Resulting Resolvent: {resolvent}")
        resolvents.add(frozenset(resolvent))
  return resolvents

# Function to perform resolution on the KB and query with detailed output
def resolution_algorithm(KB, query):
  """Perform the resolution algorithm to check if the query can be proven."""
  print("\n--- Step-by-Step Resolution Process ---")
  # Add the negation of the query to the knowledge base
  negated_query = negate(query)
  KB.append(frozenset([negated_query]))
  print(f"Negated Query Added to KB: {negated_query}")

  # Initialize the set of clauses to process
  clauses = set(KB)

  step = 1
```

```
    while True:
        new_clauses = set()
        print(f"\nStep {step}: Resolving Clauses")
        for c1 in clauses:
            for c2 in clauses:
                if c1 != c2:
                    print(f"    Resolving clauses: {c1} and {c2}")
                    resolvent = resolve(c1, c2)
                    for res in resolvent:
                        if frozenset([]) in resolvent:
                            print("\nEmpty clause derived! The query is provable.")
                            return True  # Empty clause found, contradiction, query is provable
                        new_clauses.add(res)

        if new_clauses.issubset(clauses):
            print("\nNo new clauses can be derived. The query is not provable.")
            return False  # No new clauses, query is not provable

        clauses.update(new_clauses)
        step += 1

# Knowledge Base (KB) from the image facts
KB = [
    frozenset([("not", "food(x)"), ("likes", "John", "x")]),  # 1
    frozenset([("food", "Apple")]),  # 2
    frozenset([("food", "vegetables")]),  # 3
    frozenset([("not", "eats(y, z)"), ("killed", "y"), ("food", "z")]),  # 4
    frozenset([("eats", "Anil", "Peanuts")]),  # 5
    frozenset([("alive", "Anil")]),  # 6
    frozenset([("not", "eats(Anil, w)"), ("eats", "Harry", "w")]),  # 7
    frozenset([("killed", "g"), ("alive", "g")]),  # 8
    frozenset([("not", "alive(k)"), ("not", "killed(k)")]),  # 9
    frozenset([("likes", "John", "Peanuts")])  # 10
]

# Query to prove
query = ("likes", "John", "Peanuts")
```

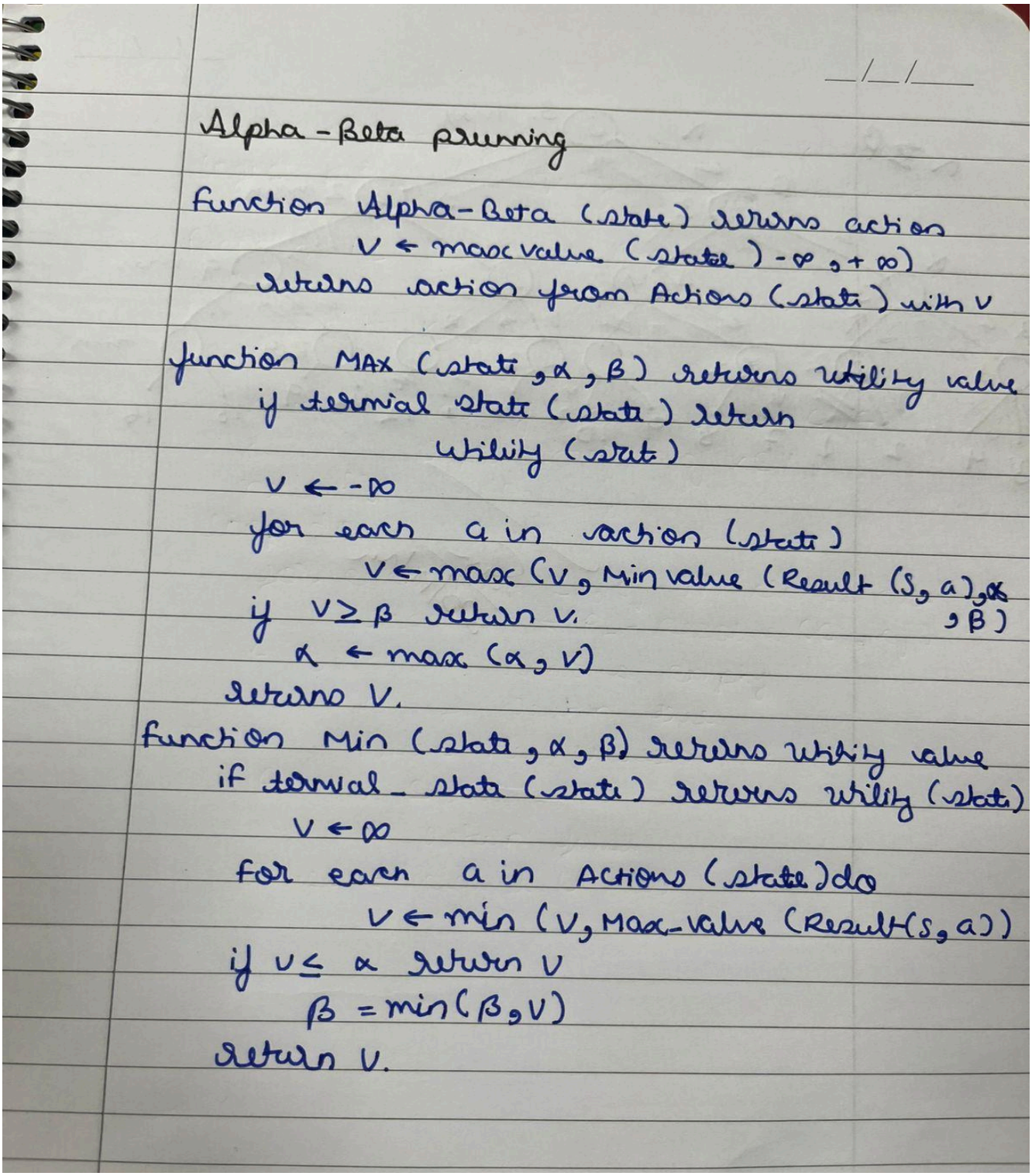
```python
# Perform resolution to check if the query is provable
result = resolution_algorithm(KB, query)
if result:
  print("\nQuery is provable.")
else:
  print("\nQuery is not provable.")

print("\nTARUN MM")
print("1BM22CS306")
```

Output Snapshot

```
--- Step-by-Step Resolution Process ---
Negated Query Added to KB: ('not', ('likes', 'John', 'Peanuts'))

Step 1: Resolving Clauses
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'alive(k)'), ('not', 'killed(k)')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('food', 'z'), ('killed', 'y'), ('not', 'eats(y, z)')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'eats(Anil, w)'), ('eats', 'Harry', 'w')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', 'food(x)'), ('likes', 'John', 'x')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('alive', 'Anil')})
    Resolving clauses: frozenset({('likes', 'John', 'Peanuts')}) and frozenset({('not', ('likes', 'John', 'Peanuts'))})
    Resolving literal: ('likes', 'John', 'Peanuts') with ('not', ('likes', 'John', 'Peanuts'))
    Resulting Resolvent: frozenset()

Empty clause derived! The query is provable.

Query is provable.
```

Program - 11 Alpha-Beta values generated to identify the final value of MAX node and subtrees pruned for a given Game tree using the Alpha-Beta pruning algorithm

Algorithm



Alpha - Beta pruning

function Alpha-Beta (state) returns action
    $v \leftarrow$ max value (state) $-\infty, +\infty$)
    returns action from Actions (state) with v

function MAX (state, α, β) returns utility value
    if terminal state (state) return
        utility (state)
    $v \leftarrow -\infty$
    for each a in action (state)
        $v \leftarrow$ max (v, Min value (Result (s, a), α, β))
    if $v \geq \beta$ return v.
        $\alpha \leftarrow$ max (α, v)
    return V.

function Min (state, α, β) returns utility value
    if terminal_state (state) returns utility (state)
        $v \leftarrow \infty$
    for each a in Actions (state) do
        $v \leftarrow$ min (v, Max-value (Result (s, a))
    if $v \leq \alpha$ return v
        β = min (β, v)
    return V.

Code

```
import math

# Alpha-Beta Pruning Algorithm
def alpha_beta_search(depth, index, is_max, values, alpha, beta, target_depth):
  """Recursive function for Alpha-Beta Pruning."""
  # Base case: If the target depth is reached, return the leaf node value
  if depth == target_depth:
    return values[index]

  if is_max:
    # Maximizer's turn
    best = -math.inf
    for i in range(2):
      val = alpha_beta_search(depth + 1, index * 2 + i, False, values, alpha, beta, target_depth)
      best = max(best, val)
      alpha = max(alpha, best)
      if beta <= alpha:
        break  # Prune remaining branches
    return best
  else:
    # Minimizer's turn
    best = math.inf
    for i in range(2):
      val = alpha_beta_search(depth + 1, index * 2 + i, True, values, alpha, beta, target_depth)
      best = min(best, val)
      beta = min(beta, best)
      if beta <= alpha:
        break  # Prune remaining branches
    return best

def main():
```

```
    # User Input: Values of leaf nodes
    print("Enter the values of leaf nodes separated by spaces:")
    values = list(map(int, input().split()))

    # Calculate depth of the game tree
    target_depth = math.log2(len(values))
    if target_depth != int(target_depth):
        print("Error: The number of leaf nodes must be a power of 2.")
        return
    target_depth = int(target_depth)

    # Run Alpha-Beta Pruning
    result = alpha_beta_search(0, 0, True, values, -math.inf, math.inf, target_depth)

    # Display the result
    print(f"The optimal value determined by Alpha-Beta Pruning is: {result}")

print("TARUN M M")
print("1BM22CS306\n")

if __name__ == "__main__":
    main()
```

Output Snapshot

```
Enter the values of leaf nodes separated by spaces:
10 9 14 18 5 4 50 3
The optimal value determined by Alpha-Beta Pruning is: 10
```